The Nutritive Value of Marine Products

VII. The Vitamin A and D Potency of the Oils from British Columbia Canned Salmon

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ABSTRACT

The total oil in samples of canned British Columbia sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon, each from three different localities, contained respectively 50, 67, 67 and 50, 67, 67 international units of vitamin D per gram, equivalent to average contents of 1700 and 880 international units in the oil per pound of contents for the sockeye and pink samples respectively. The oil in the cans of sockeye salmon from two of the localities contained approximately 2.5 and 2.0 A.D.M.A. units of vitamin A per gram respectively. A composite sample of the oil in all the cans of pink salmon contained no appreciable amount of vitamin A. Several physical and chemical characteristics of the oil samples are given.

INTRODUCTION

The salmon fishery of British Columbia is the most important fishery in Canada, accounting in recent years for almost half the fish products of the Dominion as regards marketed value. Information regarding the nutritive value and composition of British Columbia canned salmon is, however, very incomplete. Carter (1936) has reported proximate analyses of canned British Columbia sockeye salmon (*Oncorhynchus nerka*) and pink salmon (*O. gorbuscha*), while Riddell (1936) carried out similar analyses of canned British Columbia blueback salmon (*O. kisutch*). In the present work the vitamin A and D potencies of the oil from canned British Columbia sockeye and pink salmon have been investigated.

Previous Vitamin Studies

Tolle and Nelson (1931) studied the potency in vitamins A and D of the oil from canned salmon of five species of the genus *Oncorhynchus*, their samples being taken from the United States pack. They found that, while the samples of all species were relatively potent as sources of vitamin D, they were very low in vitamin A content. Truesdail and Boynton (1931) in a study of the vitamin A potency of the flesh oils of the same five species, caught in American waters, found appreciable variations between species in the amount of this vitamin, although all samples gave quite low values. No work on the vitamin potency of oil from the flesh of salmon caught in British Columbia waters has yet been reported.

Sampling

For the data of this type of investigation to be strictly representative of the season's pack in any district, a system of sampling should be arranged such that cans would be taken at regular intervals during every period of canning throughout the season, thus giving a cross-section of the pack under study. Unfortunately when the plans for the present investigation were drawn up no such samples were available, and it would have been necessary to postpone the commencement of the work for a year in order to obtain them. To avoid this delay, random lots of twenty-four 1-pound cans each were taken from the pack of each district which it was desired to study. Samples of canned sockeye salmon from the Skeena river, Rivers inlet and the Fraser river, and of pink salmon from Butedale, Johnstone strait and the Fraser river were secured.

EXPERIMENTAL

Preparation of the Oils

The free oil was prepared by pressing the contents of the cans in the cold in a small hydraulic press, separating the oil from the rest of the press liquor in a separatory funnel, and dehydrating it with anhydrous sodium sulphate. To obtain the remaining oil the press cakes were broken up and extracted with ethyl ether. The solutions thus obtained were dehydrated with anhydrous sodium sulphate, and the oil was recovered by distilling off the solvent *in vacuo*. After determining the colours and acid values of the free and extracted oils separately, they were combined for the other physical and chemical determinations, and for the vitamin assays.

Physical and Chemical Characteristics

In order to describe the samples of oil and to find their suitability for nutritional use, several physical and chemical characteristics were determined. The data for these, together with the total yields of oil expressed as percentages of the contents of the can, are given in table I.

Table I. Physical and chemical characteristics of salmon body oils

Species	Locality where caught	Per cent oil in contents of can	Colour* of free oil		Colour* of extr. oil		Acid value of free oil	Acid value extr. oil	Per cent unsaponifiable matter	Iodine value	N_D^{25}
			R	Y	R	Y					
Sockeye	Skeena river	8.2	14.4	27.8	31.2	9.8	0.38	2.18	1.14	151.5	1.4775
	Rivers inlet	5.7	14.1	27.4	28.1	10.6	0.40	2.22	1.21	145.3	1.4771
	Fraser river	5.6	14.3	27.9	32.8	9.9	0.50	1.74	1.10	135.7	1.4760
Pinks	Butedale	4.3	5.3	28.2	30.3	29.6	0.85	10.17	0.95	161.3	1.4790
	Johnstone strait	3.5	5.2	28.5	14.7	29.6	0.84	4.80	0.95	160.7	1.4784
	Fraser river	2.0	4.0	16.4	15.2	25.8	0.88	5.86	1.38	157 4	1.4780

*R = Lovibond red units
Y = Lovibond yellow units

As seen from the data in table I, the acid values of the free oils were all low and were closely grouped for each species, while the acid values of the extracted

oils were high and, particularly in the case of the pink salmon, showed great variation. The explanation of this has been found by Brocklesby (1933) to be due to non-fatty water soluble acidic substances naturally present in the flesh of the salmon which are extractable only with difficulty by the oil, but are readily soluble in the ethyl ether used to extract the oil. Such substances include lactic acid.

The iodine value of an oil is very useful as a measure of its degree of unsaturation and, when the oil is free from oxidized or polymerized material, it bears an approximately direct relationship to the refractive index (Notevarp and Pillgram-Larsen 1933). In the case of these samples, if any oxidation or polymerization took place in the oils during the processing of the canned fish, it was not sufficient to prevent a definite parallelism being evident.

The low values found for the percentages of unsaponifiable matter are a further indication of the suitability of the oils for use in human nutrition.

Vitamin A Determinations

Three samples of oil, Skeena river sockeye, Fraser river sockeye and a composite sample of the three pink salmon oils were assayed biologically for vitamin A. Determinations were carried out by the method of bio-assay recommended by the Vitamin Assay Committee of the American Drug Manufacturers Association (1931), the essentials of which were as follows. Young albino rats of a homozygous strain were reared from mothers fed a stock diet found to give low storage of fat-soluble vitamins. They were weaned 21 days after birth and continued on this stock ration until from 25 to 29 days old, when those weighing from 38 to 45 gm. were segregated for use in the test and fed the following vitamin A-free diet:

	Percentage
Casein (vitamin A-free)	18
Salt mixture (McCollum No. 185)	4
Agar	2
Yeast (dried)	8
Corn starch	63
Hydrogenated vegetable oil (Crisco)	5

Vitamin D—5 international units per day.

When the rats had been maintained on this diet for a period of approximately one month they ceased to grow and began to lose weight. The animals, after showing constant or declining weight for a period of one week were given the vitamin A supplements, either vitamin A standard or test substance, in suitable amounts. A suitable number of negative control animals were also maintained during the test period. For uniformity the administration of the supplements was not begun before the thirtieth or after the forty-fifth day of the vitamin A-free preparatory period. Any rats not meeting these criteria were rejected. The supplements were fed daily for a period of 8 weeks; growth data were recorded twice weekly. The positive control animals received daily 2 mg. of a medicinal cod liver oil which contained 500 A.D.M.A.* units of vitamin A per gm. All oils were

*American Drug Manufacturers' Association.

administered from feeding pipettes made in the laboratory, and calibrated to deliver 20 or 40 mg.

Preliminary tests of one of the sockeye oils and the composite pink salmon oil indicated that the vitamin A potencies were very low. These preliminary data are not reported. In order to avoid the consequently large dosages of oil which were necessary when the natural oil was fed to the animals, the oil was saponified; the unsaponifiable matter was extracted and dissolved in a small amount of Wesson oil for feeding. Since it was desired only to concentrate the vitamin and not to remove the oil altogether, a single cold saponification was used. After saponification the soaps were dissolved in fifth normal potassium hydroxide and the unsaponifiable matter was extracted with ethyl ether. The ethyl ether solution was washed with an equal volume of fifth normal potassium hydroxide and then with successive quantities of distilled water until free from alkali. After dehydration with anhydrous sodium sulphate the ether was removed by distillation *in vacuo*. A small quantity of Wesson oil was added to the ethereal solution before distillation in order to facilitate the solution of the unsaponifiable matter and the small amount of soap which always accompanied it. When this was not done, some difficulty was encountered in dissolving in oil the residual material which remained after distilling off the solvent. In all manipulations the materials were kept in an atmosphere of inert gas.

The data of the bio-assays for vitamin A are given in table II.

TABLE II. Bio-assay for vitamin A in salmon body oils

Oil used in test	Oil feeding level in mg.	No. of rats	Number surviving test period*	Av. gain per week in gm.
Skeena river sockeye	150	4	0	
" " "	200	6	1	−4.0
" " "	250	6	2	−1.0
" " "	350	5	4	3.1
Fraser river sockeye	350	6	0	
" " "	400	5	5	4.8
" " "	500	6	5	5.6
Composite pink salmon	400	7	1	−4.5
Cod liver oil	2	7	7	7.1
Negative controls		7	0	

*Test period = 8 weeks.

From the data in table II it is evident that none of the feeding levels of salmon oil supplied the animals with as much vitamin A as the positive control dosage of cod liver oil. The average growth rate of the positive controls was 7.1 gm. per week; of the rats on the 500-mg. level of Fraser river sockeye oil, 5.6 gm. per week; of those on the 350 mg. level of Fraser river sockeye oil, 5.6 gm. per week; of those on the 350 mg. level of Skeena river sockeye, 3.1 gm. per week. However, while all the rats on the 350-mg. level of Fraser river sockeye died during the test period, four of those on the 350-mg. level of Skeena river

sockeye survived and, as already pointed out, made a small gain. The sample of Skeena river sockeye oil tested was thus more potent than the sample of Fraser river oil. These two samples of oil, by comparison with the results obtained with the cod liver oil standard, therefore contained approximately 2.5 and 2.0 A.D.M.A. units of vitamin A per gm. respectively. Seven rats each receiving daily the vitamin A from 400 mg. of the composite pink salmon oil did not show any response, indicating that vitamin A, if present, was very slight in amount. At the time this work was carried out (1932-3) the International Standard Vitamin A had not come into general use and the A.D.M.A. technique was selected as a reliable method. One A.D.M.A. unit is now accepted as approximately 1.4 international units of vitamin A (Cook 1934).

Vitamin D Assays

For the determination of vitamin D the technique recommended by the Vitamin Assay Committee of the American Drug Manufacturers' Association (1931) was employed, but the standard substance fed to the positive controls was irradiated ergosterol (synthetic vitamin D) standardized by comparison with the International Standard Preparation of vitamin D. The latter was obtained from the National Institute for Medical Research, Hampstead, England. Young albino rats were reared from the same stock and by the same technique as the ones used for the vitamin A test. When from 29 to 32 days old, those weighing between 45 and 60 gm. were transferred to Steenbock's rachitogenic Diet No. 2965, the composition of which was:

	Per cent
Whole yellow corn (freshly ground)	76
Wheat gluten	20
Calcium carbonate	3
Sodium chloride	1

After 23 days on this diet, one rat from each litter was killed and examined by means of the "line test" of McCollum, Simmonds, Shipley and Park (1922). If a satisfactory degree of rickets had been developed the remainder were divided into groups for administration of the supplements, either standard vitamin D or test substance, and for use as negative controls. Six successive daily doses of the vitamin D supplements were given, and on the seventh day the rats were killed and the degree of healing measured by the line test. The test oils were fed to the animals in dosages of 20 and 40 mg. from specially-made feeding pipettes of the same type as were used in the vitamin A determinations. When a test level was not an integral multiple of 20 mg. the test oil was diluted with Wesson oil. The positive controls received one international unit of vitamin D daily, made up from a concentrated solution in corn oil diluted with Wesson oil. The data are given in table III.

The number of units of vitamin D per gm. was calculated by dividing into 1000 the number of milligrams of oil which, when administered to a group of albino rats that had been depleted of their body reserve of vitamin D and had

developed a rachitic condition, caused approximately the same average degree of healing as one international unit of the standard preparation of vitamin D. Since the oil feeding levels were varied, across the significant range, in steps of 5 mg., the vitamin D potencies in international units per gram also varied in steps, the magnitude of which depended upon the particular levels under scrutiny.

TABLE III. Bio-assay for vitamin D in salmon body oils

Sample	Oil feeding level in mg.	No. of rats	Line test results						Units per gram
			No healing	Very slight	1+	2+	3+	4+	
Skeena river sockeye	10	3	3						50
" " "	15	7	5	1	1				
" " "	20	6	2	1	2	1			
" " "	40	2					2		
Rivers inlet sockeye	10	7	6	1					67
" " "	15	6	2	2	1	1			
" " "	20	4			2	2			
" " "	25	5			2	2	1		
" " "	30	4				2	2		
" " "	40	3						3	
Fraser river sockeye	10	6	4	2					67
" " "	15	6	1	1	1	3			
Butedale pink salmon	10	6	5		1				50
" " "	15	6	3		2	1			
" " "	20	6			6				
" " "	40	2					2		
Johnstone strait pink salmon	10	6	5	1					67
" " " "	15	6		1	2	3			
Fraser river pink salmon	10	6	5		1				67
" " " "	15	6			4	2			
Irradiated ergosterol	0.0002	18	3	4	6	5			
Med. Res. Irradiated Ergosterol	0.0001	7	3		2	2			
Negative controls		13	13						

As shown in table III, the vitamin D potency of four of the samples was 67 international units per gm., and of two, 50 international units per gm. The data show that the oil from canned British Columbia salmon is a comparatively rich source of vitamin D, although the original sampling was not sufficiently representative for general conclusions to be drawn in regard to the vitamin D value of the oil in the pack from the various districts studied. Cod liver oil, a common medicinal source of vitamin D which may be used for a comparison, contains from 80 to 200 international units of vitamin D per gm.

From the percentages of oil given in table I, and the vitamin D potencies given in table III, it is calculated that the average vitamin D content in the oil from a pound of canned sockeye salmon was 1700 international units, and from a pound of canned pink salmon, 680 international units.

CONCLUSIONS

Canned sockeye salmon and pink salmon prepared from fish caught in British Columbia waters are good sources of vitamin D. In the examination of the present samples it was found that canned salmon of both species had the same average vitamin D potency. Due to the lower oil content of the pink salmon, however, the average vitamin D potency of the total can contents was higher in the sockeye. Vitamin A is a negligible factor in the canned fish from both species.

SUMMARY

The oils from three samples of canned British Columbia sockeye salmon and three samples of canned British Columbia pink salmon from various localities have been assayed biologically for vitamin D using albino rats. In each species the vitamin D potency of one of the samples was 50 international units per gm., and of two of the samples, 67 international units per gm. Two of the samples of canned sockeye salmon oil and a composite sample of the oils from the pink salmon samples were assayed biologically for vitamin A. The two samples of sockeye salmon oil contained approximately 2.5 and 2.0 A.D.M.A. units of vitamin A per gm. Vitamin A-depleted rats which were fed the vitamin A from the composite sample of pink salmon oils at the level of 400 mg. per day showed no response. The oil samples were examined physically and chemically and were found to be of excellent quality for nutritional use.

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The Nutritive Value of Marine Products

VIII. Proximate Analysis of Canned British Columbia Sockeye and Pink Salmon

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ABSTRACT

The proximate compositions and calculated calorific values of individual and composite samples of canned sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon from fish caught in several localities on the British Columbia coast are compared. The resulting data are also presented in such a way as to allow comparison of the composition and energy content of the various constituents in the can, some of which are frequently discarded in the utilization of canned salmon.

The average percentages of the total oil, protein, salt (sodium chloride)-free minerals, and Calories contributed by the different constituents in the samples were respectively: *flesh*—(sockeye) 62, (pink) 72; 85, 81; 55, 54; 73, 78; *skin*—(sockeye) 11.2, (pink) 15.3; 3.6, 4.3; 9.8, 6.7; 7.7, 9.0; *free aqueous liquor*—(sockeye) 0, (pink) 0; 11, 14; 5, 7; 4, 8; *free oil*—(oil) 26, 10; (Calories) 15, 4; *bone*—(salt-free minerals) 30.2, 32.6. Corresponding average percentage compositions of composite samples of entire contents were: water—(sockeye) 68.6, (pink) 71.5; oil—8.82, 6.75; protein—20.2, 19.3; salt-free minerals—1.57, 1.57. The average energy contents were (sockeye) 749, (pink) 644 Calories per pound.

Comparison with published analyses of canned sockeye and pink salmon from Alaska and Washington indicated that more extensive and detailed sampling will be necessary before conclusions can be drawn regarding the comparative compositions and food values of canned British Columbia salmons, and the relation of these values to those of salmon caught to the north and south.

INTRODUCTION

Canned salmon is the most valuable of the products obtained from the fisheries of the province of British Columbia, yet practically no data relating to the chemical composition and food value of this product appear in the literature.

Of the five species of salmon and one species of trout (steelhead) canned annually on the coast of British Columbia, the sockeye salmon (*Oncorhynchus nerka*) is of greatest commercial value. The pink (*O. gorbuscha*), coho (*O. kisutch*) or chum (*O. keta*) salmon variously come second in value in different years. The present paper deals with the proximate analysis for water, ether extract, protein and mineral in the separate constituents (free aqueous liquor, flesh, skin, bone), as well as total contents, in samples of canned sockeye and pink salmon from various localities off the coast of this province. Energy values have been computed from the amounts of ether extract and protein determined.

Extensive analyses of canned salmon from the coasts of Alaska and the north-western United States have shown that appreciable variations exist in the fat content and energy value per pound of salmon caught in these two territories. The data now presented allow a comparison of the composition of canned salmon from several widely separated points in British Columbia waters with that of salmon taken off the coasts to the north and south.

Previous Analyses of Canned Salmon

The first detailed analyses of canned salmon as reported by Atwater (1888) appear to have been made on coho caught off California. Since then various investigators have analyzed canned salmon of all species (Langworthy 1907; Loomis 1912; Clark, Clough, Fellers and Shostrom 1923; Dill 1925 and others).

Table I. Average composition of Alaska and Washington canned sockeye and pink salmon (Condensed from the data of Shostrom, Clough and Clark 1924)

Sample	Bone %	Bone-free fish				
		Moisture %	Fat %	Protein %	NaCl-free ash %	Calories per pound
Sockeye						
Special pack:						
West. Alaska	1.99	68.88	6.90	20.90	1.36	680
Cent. Alaska	2.12	68.78	6.65	21.49	1.30	680
SE. Alaska	1.67	66.62	8.92	21.56	1.33	777
Puget sound	2.32	63.44	10.29	20.53	1.23	815
Columbia R.	2.19	61.28	15.45	20.26	1.31	1028
Commercial pack (various localities)	2.37	64.78	11.22	20.80	1.23	860
Pink						
Special pack:						
West. Alaska	2.31	69.81	7.31	20.09	1.25	681
Cent. Alaska	2.33	71.07	5.12	20.90	1.34	605
SE. Alaska	2.34	69.61	6.58	20.57	1.33	660
Puget sound	2.20	68.23	6.11	20.57	1.33	640
Commercial pack (various localities)	2.53	69.80	6.99	21.40	0.76	696

Probably the most comprehensive investigation is that reported by Shostrom, Clough and Clark (1924) who made analyses of specially prepared and commercial samples of all the species of salmon canned in Alaska and the Pacific north-western States. The special samples were cans containing cross-sections from the same part of the gutted fish in order to eliminate the already demonstrated variation in composition of sections from the neck and tail of one fish. In spite of this precaution, wide variations in the percentages of various constituents were found in cans containing different fish of the same species caught in the same locality on the same day. Cans from commercial samples, which sometimes contain various cuts from one or more fish, exhibited even greater variations. Moreover, the average composition of salmon of the same species, caught in the same locality at

the same period of the fishing season, was shown to vary from year to year. Table I gives a summary of the data for sockeye and pink salmon examined in the investigation just described.

A significant decrease in moisture content and increase in fat and energy content was observed as the locality, in which the sockeye salmon were caught, changed from north to south, but this regular variation was not so evident in the case of the pink salmon.

Dill (1925) and Clark and Almy (1918) have shown that the earliness or lateness of the catch in relation to the season also has an appreciable effect on the chemical composition of canned salmon of any one season. Some interesting observations on the depletion of body reserves of fat to supply energy as salmon migrate up river to spawn have been made by C. W. Greene (1919, 1921), C. H. Greene (1919), and Pentegov, Mentov and Kurnaev (1928).

PROCEDURE

Sampling

From the foregoing summary of previous investigations it is apparent that reliable data on the comparative compositions of canned samples of different species of British Columbia salmon, or of the same species as influenced by locality and earliness or lateness of run, may be secured only by a very extensive sampling programme extending over several years. Furthermore, the examination of samples containing a number of cans sufficient to eliminate apparent differences in composition due to variations among the individual cans, caused by commercial packing conditions, would be necessary. Such a programme was not feasible at the time of commencing this investigation; and sample lots of twenty-four one-pound cans each were obtained from the commercial pack from the localities given in table II.

TABLE II. Description of samples

Species	Locality	Latitude	When canned
Sockeye	*Skeena river	54° 10′	July 22, 1931
	*Rivers inlet	51° 30′	July 22-27, 1930
	Fraser river, off mouth	49° 10′	Sept. 15, 1931
	Fraser river, up stream	49° 10′	Oct. 7-8, 1931
Pink	Butedale	53° 10′	Aug. 14, 1931
	Bones bay	50° 30′	Early in 1931 season
	Fraser river, up stream	49° 10′	Sept. 15, 1931

*1-lb. flat cans; all other samples were 1-lb. tall cans.

Table II indicates that the lots were from salmon caught in localities representing fairly well the geographical range of salmon canning activity on the British Columbia coast. The seasonal period of greatest run of fish is earlier in the north than in the south for sockeye and pink, and with the exception of the late-run sockeye from the Fraser river, the lots were canned during a period of average run of fish in that locality. Hence the geographical and seasonable variables are

superimposed on one another in such a way that scarcely any significant conclusions may be drawn regarding the effect of either on the composition of the canned product. The data given later, therefore, are representative only of a cross-section of the effects of both geographical and seasonal variations on certain constituents of canned sockeye and pink salmon separately.

A sub-sample of twelve cans was taken at random from each of the seven lots of twenty-four cans. The contents of six cans from each sub-sample were submitted to individual examination and analysis; the contents of the remaining six cans from each sub-sample were united to form separate composite samples.

Examination and Preparation of Samples for Analysis

Before each can taken for individual analysis was examined, the vacuum and net weight of contents were determined. The amounts of free oil and aqueous liquor, flesh, skin and bone were then determined (table III) in order to assess later their separate food values.

VACUUM

This was determined by a mercury manometer gauge and the results were expressed in centimetres of mercury and corrected to a temperature of 18°C.

NET WEIGHT OF CONTENTS

The net weight was taken as the difference between the weight of the unopened can and that of the empty can after brushing out all adhering pieces of skin or flesh.

FREE OIL AND AQUEOUS LIQUOR

The free oil and aqueous liquor in the cans, and any additional liquid separating on breaking apart the flesh, were decanted, allowed to separate and the volume of each was measured.

SEPARATION OF FLESH, SKIN, AND BONE

After the free liquids had been decanted, all skin adhering to the muscle tissue (flesh) or to the interior of the can was placed in a tared beaker. Any solid material other than flesh and bone, such as membranous tissue, spinal nerve cord, dorsal blood vessel, coagulated material between the vertebrae, and other coagulated material, was also separated and added to the skin, which was then weighed. The vertebrae and all smaller bones were removed and weighed in a tared Soxhlet extraction thimble. The flesh remaining was passed through a meat grinder into a tared beaker, the grinder was "rinsed" with some of the pulpy, finely ground flesh, and brushed out into the beaker. The oil and aqueous liquor in the graduate were then added to this beaker, the graduate was rinsed with a portion of the ground flesh reserved for this purpose, and the entire contents of the beaker were thoroughly mixed and weighed. Small samples (about 50 g.) were then weighed out for analysis. The allocation of the entire amount of free oil and aqueous liquor to the flesh was adopted since it was no longer possible to assign the proper proportions to the tissues from which they originally exuded during the canning process.

ENTIRE CAN CONTENT

The separation procedure just described permitted a reconstruction of the composition of the entire content of the cans from the analytical data obtained later. It was considered desirable, however, to undertake in addition analyses of the unseparated contents. Seven composite samples were prepared by mixing thoroughly the entire contents of each group of six cans remaining in the sub-samples from the seven original samples. Small portions (about 100 g.) were then weighed out.

For reasons mentioned later, a separate determination of the food values of the free oil

and aqueous liquor was desired. The data presented in table III sufficed for calculating the energy content of the free oil, but the constituents of the liquor had to be determined from separate samples. Owing to the uncertainty regarding the extent to which this liquor may be drained off, and the tendency for solid material to be included with it, no detailed sampling was undertaken. Two samples only, from composite samples of each of the two species, were analyzed (table VIII).

Analysis

WATER CONTENT

Loss in weight of duplicate samples after drying to constant weight at 70 to 80°C. under 2 to 3 cm. pressure was taken as the content of water. Vacuum drying avoided oxidation of the oil, and the intumescence of most of the samples permitted much more rapid drying than in the case of samples dried at 105°C. under atmospheric pressure. The condensed liquid developed a slight scum of crystalline nitrogenous material which was discarded.

The water content of the separate sample of free liquor was determined similarly by evaporating weighed, 100-ml. portions to dryness in a vacuum distillation flask.

ETHER EXTRACT

The anhydrous flesh and skin samples were coarsely ground in a mortar, allowed to stand in a desiccator over-night and weighed out into tared Soxhlet extraction thimbles. Duplicate samples of the flesh, skin, and bone were then extracted with anhydrous ethyl ether for 12 hours in a Soxhlet extractor and dried to constant weight at 100°C. The loss in weight was taken as the content of "anhydrous ethyl ether extract", hereinafter referred to as "oil". For the extraction of the composite samples of total can content, and of the solids in the aqueous liquor, petrol ether was used as it was more readily kept anhydrous. A separate experiment showed a non-significant difference in the percentages of oil extracted from anhydrous salmon flesh by these two solvents after 12 hours.

For the purpose of determining the nitrogen and mineral contents of the flesh, skin, and bone it was considered unnecessary to analyze separately the corresponding constituents from each can. Consequently the appropriate solids were united to give seven composite samples of these constituents. In order to secure complete homogeneity before removing the small portions required for the following analyses, these solids were ground until all material passed through a piece of bolting silk having 15 threads to the centimetre. Each was then thoroughly mixed and allowed to stand in a desiccator overnight. The composite samples of entire can contents and the solids from the aqueous liquor were similarly treated.

NITROGEN

The Kjeldahl-Gunning procedure was employed, whereby digestion of approximately 0.3 g. duplicate samples was complete in 2 hours. The data for nitrogen content were then converted into terms of protein by multiplication by the factor 6.25. This factor is undoubtedly open to criticism when used for calculation of the protein content of fish skin and bone, owing to the existence of complex proteid substances. Its use for the protein in fish muscle is also open to question (Jones 1931). A positive test for nitrogen was obtained from some of the samples of extracted oils, but the amount was negligible and was not taken into consideration.

ASH

Approximately 2 g. duplicate samples were weighed out into tared porcelain crucibles and ashed in an electric muffle furnace at about 750°C. The samples of bone and skin reduced to a white or gray ash without difficulty, but the flesh and composite samples tended to sinter and enclose particles of unburnt carbon. Such samples were therefore partially ashed, extracted with boiling water, and the residue completely ashed. The extract was then added to the crucible, evaporated to dryness, and the whole brought to a dull red heat for a few minutes. The crucibles were then re-weighed after cooling in a desiccator.

SODIUM CHLORIDE

Since this salt is added during the canning process, it was desirable to determine this constituent separately. The total halogen ions in aqueous extracts of the ashed samples were titrated with N/10 silver nitrate solution by Mohr's method in the case of the skin and bone, and by Volhard's method in the case of the flesh and composite samples. The data for the weight of halogen were converted into terms of sodium chloride.

SALT-FREE ASH

The differences between the weights of ash and of sodium chloride were taken as representing "salt-free ash".

ENERGY VALUES

The energy or calorific values of the oil and protein were computed from the determined weights of these constituents, using the data of Rubner (1901); namely, 1 gram of oil is equivalent to 9.3 Calories, and 1 gram of protein is equivalent to 4.1 Calories. Calculated on the basis of one pound (454 g.) of material, each per cent of oil is equivalent to 42.2 Calories, and each per cent of protein is equivalent to 18.6 Calories.

The possible contribution to the energy content by carbohydrates was ignored since the carbohydrate content of fishes has been shown (Greene 1921; Macleod and Simpson 1927) to be negligible. This is particularly the case in canned fish where the internal organs are absent.

DISCUSSION OF DATA

Examination of Samples (Table III)

WEIGHT

The average weights of contents shown in table III indicate that in general these "1-pound" cans contained well over a pound (454 g.) of contents. The more representative data obtained by later examination of all the cans available indicated that the averages shown for the sub-samples agreed very closely with the averages for the entire samples. The minimum and maximum recorded weights of contents were 418 g. (14.8 oz.) and 502 g. (17.8 oz.) respectively.

VACUUM

A considerable range of vacuum was to be anticipated since some canneries produce the vacuum by pre-heating the filled cans to 90-100°C. before sealing, while others employ a machine that seals the cold, filled cans in a chamber under constant vacuum. Whichever method is used, a final vacuum of at least 20 cm. (8 in.) of mercury at about 15°C. at sea level is desirable, in order that increases in temperature and altitude later experienced by the cans may not cause them to lose their vacuum or become "springers". A considerable proportion of the two lots of 1-pound flat cans examined contained less than the recommended 20-cm. vacuum.

FREE OIL AND AQUEOUS LIQUOR

The fact that the volumes of oil and liquor in canned salmon are known to increase slightly with the time that has elapsed since canning, and the uncertainty of the draining due to differences in the tightness of packing, do not allow any particular significance to be attached to the data for these liquids in table III. It is of interest, however, to note the rough parallelism between the separate average

TABLE III. Summary of examination of samples* of canned B.C. sockeye and pink salmon

Sample	Weight contents grams	Vacuum cm. Hg.	Free oil ml.	Free aqueous liquor ml.	Weight of		
					flesh** grams	skin grams	bone grams
Sockeye:							
Skeena river							
range	433-483	9-27	10-24	42-71	386-447	24-40	3.2-7.5
average	461	16	15	53	423	32	6.0
Rivers inlet							
range	419-496	6-31	6-23	41-70	384-453	21-37	4.3-8.8
average	457	19	13	56	422	28	7.1
Fraser river (off mouth)							
range	464-493	16-28	10-25	37-70	424-462	23-41	5.0-7.8
average	478	24	17	59	440	31	6.9
Fraser river (up stream)							
range	448-491	28-39	2-14	54-84	432-465	5-35	2.3-9.9
average	476	33	8	66	451	18	7.5
Pink:							
Butedale							
range	451-488	21-35	2-6	59-73	418-453	21-44	4.5-7.9
average	473	30	4	67	435	32	6.5
Bones bay							
range	458-489	21-43	3-8	62-81	424-477	21-38	1.0-10.0
average	474	33	5	73	445	22	6.9
Fraser river							
range	463-484	36-43	1-2	115-120	423-453	20-35	8.2-13.4
average	476	39	1	118	438	27	11.6
Av. for sockeye	468	..	13	59	434	27	6.9
Av. for pink	474	..	3	86	439	27	8.3

*Separate averages are for six individual cans.
**Including free oil and aqueous liquor.

volumes of oil and liquor and the corresponding averages for total oil and water content in the cans as shown in table V. A crude complementary relation between the averages for the free oil and liquor of each sample also is evident. Clark, Clough, Fellers and Shostrom (1923), from the examination of some 6000 cans of Pacific salmon, give the following average values for free oil and liquor. Free oil—sockeye, 7.3 ml. (range, 1.0 to 40 ml.); pink, 3.8 ml. (range, 0 to 23 ml.). Free liquor—sockeye, 53 ml. (range, 44 to 120 ml.); pink, 70 ml. (range, 23 to 135 ml.). The averages shown at the bottom of table III indicate that the present samples of British Columbia sockeye had a high free oil and normal liquor content, while the pink had a slightly low free oil and high liquor content, as compared with the averages found by the above authors.

FLESH, SKIN, AND BONE

The low average weight of skin shown in table III for the fourth sample of

sockeye was due to the absence of skin in three of the six cans examined. Inspection of the balance of the cans in this lot disclosed a similar proportion of cans without skin. The skin from late-run fish sometimes becomes separated from the flesh by the plunger of the mechanical filling machine, or on occasions the skin is purposely removed from the fish. The complete absence of vertebrae in two cans examined was probably explained by mechanical filling, while the high average weight of bone in the Fraser river pink sample was caused by the presence in the cans of several small "steaks", each containing its section of vertebrae. Part of the variations in both ranges and averages for skin and bone is undoubtedly also due to the non-uniformity of the samples with respect to section of fish used to fill the can.

Proximate Analysis of Flesh, Skin, and Bone (Table IV a, b, c)

WATER AND OIL

The ranges and averages for percentages of both water and oil in the bone

Table IV (*a*). Proximate analysis of flesh (including free oil and aqueous liquor) in samples* of canned B.C. sockeye and pink salmon

Sample	Water	Oil	Solids	Solids		
				Protein	Salt-free ash	Salt
	%	%	%	%	%	%
Sockeye						
Skeena river						
range	62.3-71.2	7.3-14.5	20.9-24.2	....	...	...
average	67.1	9.9	23.0	90.6	3.8	4.3
Rivers inlet						
range	64.1-70.1	5.6-13.1	22.9-24.3	....	...	...
average	67.3	9.2	23.5	92.4	3.3	4.2
Fraser river (off mouth)						
range	62.6-71.2	6.3-14.6	20.8-23.1	....	...	...
average	67.4	10.1	22.5	93.8	4.2	3.2
Fraser river (up stream)						
range	66.5-72.7	3.8-12.0	21.5-23.5	....	...	...
average	69.6	8.1	22.3	87.8	4.0	6.3
Pink:						
Butedale						
range	69.5-72.2	4.5-7.8	22.6-23.8	....	...	...
average	70.9	5.9	23.4	91.0	5.2	3.4
Bones bay						
range	68.5-71.6	4.8-8.7	22.4-24.2	....	...	...
average	70.2	6.5	23.4	88.7	4.7	6.2
Fraser river						
range	72.2-77.3	2.2-6.1	20.0-21.8	....	...	...
average	75.6	3.9	20.5	91.5	3.1	4.9
Av. for sockeye	67.9	9.3	22.8	91.3	3.8	4.5
Av. for pink	72.2	5.4	22.4	90.4	4.3	4.8

*Separate averages in columns 2, 3 and 4 are for six individual cans; figures in columns 5 6 and 7 are for composite samples of six cans.

(table IVc) showed little variation, as would be expected, and the average for each in the two species were practically identical. The ranges for percentage of water in the flesh and skin (tables IVa, b) were not great, but the ranges for percentage of oil were considerable.

As already pointed out, the free oil and aqueous liquor were added to the flesh before analysis. Consequently little significance may be attached to com-

TABLE IV (*b*). Proximate analysis of skin in samples* of canned B.C. sockeye and pink salmon

Sample	Water	Oil	Solids	Solids		
				Protein	Salt-free ash	Salt
	%	%	%	%	%	%
Sockeye:						
Skeena river						
range	57.5-67.0	16.3-27.3	14.9-16.7	....	....	...
average	63.2	21.1	15.8	82.6	13.1	4.4
Rivers inlet						
range	61.0-74.3	7.5-27.8	10.6-19.9	....	....	...
average	65.1	18.9	16.0	84.4	16.1	3.1
Fraser river (off mouth)						
range	60.1-74.2	8.7-24.4	15.3-17.9	....	....	...
average	68.5	15.2	16.3	84.6	13.2	3.5
Fraser river (up stream)						
range	55.6-72.6	12.9-30.3	12.9-19.7	....	....	...
average	64.3	20.1	15.6	78.8	14.0	6.5
Pink:						
Butedale						
range	54.5-70.5	13.8-33.1	12.4-17.0	....	....	...
average	63.5	21.6	15.0	87.6	9.2	4.2
Bones bay						
range	61.6-65.4	17.8-23.5	13.2-16.8	....	....	...
average	63.7	20.5	15.8	84.4	10.7	5.7
Fraser river						
range	76.1-82.1	1.1-7.5	13.7-16.9	....	...	...
average	79.2	5.1	15.8	87.7	9.9	3.6
Av. for sockeye	65.3	18.8	15.9	82.6	14.1	4.3
Av. for pink	68.8	15.7	15.5	86.6	9.9	4.5

*Separate averages in columns 2, 3 and 4 are for six individual cans; figures in columns 5, 6 and 7 are for composite samples of six cans.

parisons of the apparent relative oil contents of the skin and flesh or to variations in the apparent oil content of the skin because of the uncertainty as to the origin of the free oil and the varying amount that adhered to the skin and other tissues during their separation. However, owing to the relatively small amount of skin, subcutaneous and connective tissues as compared with the amount of flesh in a can, the bulk of the free oil can be attributed to the flesh and the wide ranges for percentages of oil in the flesh are significant. Since the fish contained in any one

sub-sample examined were canned on the same day, and were very likely caught during one day in one locality, the wide ranges must be due partly to differences in the individual fish, and partly to the variation in the section of the fish that happened to be filled into the can. That the latter cause is significant was demonstrated by Shostrom, Clough and Clark (1924), who found that the percentage

TABLE IV (*c*). Proximate analysis of bone in samples* of canned B.C. sockeye and pink salmon

Sample	Water	Oil	Solids	Solids		
				Protein	Salt-free ash	Salt
	%	%	%	%	%	%
Sockeye:						
Skeena river						
range	53.8-59.7	5.4-6.5	33.8-40.5	....	....	...
average	56.1	6.0	37.8	13.4	71.8	0.1
Rivers inlet						
range	53.0-68.4	5.5-6.4	25.2-41.5	....	....	...
average	59.2	6.1	34.7	14.0	71.1	0.1
Fraser river (off mouth)						
range	51.2-56.3	5.5-6.1	37.6-43.3	....	....	...
average	54.7	5.9	39.5	11.3	71.3	0.3
Fraser river (up stream)						
range	49.4-61.6	5.1-6.7	31.7-45.5	....	....	...
average	56.3	6.1	37.6	10.9	74.3	0.2
Pink:						
Butedale						
range	51.5-55.4	5.7-6.1	38.7-42.5	....	....	...
average	53.5	5.8	40.6	13.2	67.0	0.2
Bones bay						
range	50.4-64.8	5.4-6.9	28.3-44.2	....	....	...
average	57.1	6.1	36.8	13.3	69.5	0.1
Fraser river						
range	51.0-69.0	5.4-7.6	23.4-43.6	....	....	...
average	57.1	6.2	36.7	13.8	69.0	0.2
Av. for sockeye	56.6	6.0	37.4	12.4	72.1	0.18
Av. for pink	55.9	6.0	38.0	13.4	68.5	0.17

*Separate averages in columns 2, 3 and 4 are for six individual cans; figures in columns 5, 6 and 7 are for composite samples of six cans.

of oil in cross-sections of the flesh near the tails of spring salmon (*O. tschawytscha*) was approximately 45% less than that in cross-sections near the heads.

As would be expected, the average percentages of water and oil (and solids) in the flesh of each species closely resembled those shown in table V for the complete can contents; consequently the same rough parallelism to the amounts of free oil and liquor existed.

SOLIDS

The ranges for content of flesh solids were narrow, and the averages for both species almost identical. Slightly wider ranges appeared for the skin and bone although the separate averages and averages for both species remained fairly uniform in each constituent. Differences in the amount of scale material adhering to the skin and in the porosity of the vertebrae in different parts of the fish would account for part of each range.

The protein, mineral, and salt contents of the solids in tables IV a, b, c are expressed as percentages of the dry weight to eliminate as far as possible the effects of the arbitrary allocation of the free oil and aqueous liquor to the flesh.

PROTEIN

No striking differences in the average percentages of protein in the solids of the flesh, skin or bone between the two species were evident. The only variation of significance to the food value of different samples of the same species occurred in the flesh of the late-run sockeye from the Fraser river, in which, as with the skin, the protein content was somewhat smaller.

SALT-FREE ASH

The difference between the average ash content of the skin of sockeye and pink was the only striking feature of the ash analyses.

SALT

As already mentioned, sodium chloride is added to the fish during canning and consequently these data have little bearing on the natural constituents of the flesh, skin or bone. The high salt content of the solids in the flesh and skin of one sample of both sockeye and pink is evident, and in the case of the sockeye sample, was probably intentional to offset the "flatness" of late-caught fish.

The percentages of constituents in any one analysis of bone solids never totalled 100. This is attributable to the use of the questionable factor 6.25 in calculating the protein from nitrogen content, and to the loss of gases such as carbon dioxide when reducing the large mineral content to ash.

COMPOSITION OF ENTIRE CAN CONTENT (TABLES V, VI)

Table V gives a summary of the proximate chemical composition and calorific value of the total contents of the cans as reconstructed from the separate analyses of the flesh (including free oil and liquor), skin, and bone and summarized in tables IVa, b, c. The subdivided nature of the analyses and use of aliquant samples for analysis makes the separate data shown in this table less reliable than those in table VI, although some experimental errors would tend to be compensated in calculating the averages for the two species, shown at the bottom of table V. This table is of interest, however, since it allows the inclusion of the ranges of percentages of water, oil, and solids.

WATER

From the separate analysis of twenty-four cans of sockeye and eighteen cans of pink salmon, it is evident from both the ranges and averages shown in table V that the percentage of water in the former was less than that in the latter.

OIL

The wide ranges in table V, as well as the similarly wide ranges shown in table IVa and the remarks thereto, indicate that, from such small sample lots, any attempt to compare the average oil content in cans of the same species of fish from different localities must be viewed with caution. Sockeye is generally conceded as superior to pink salmon in oil content, and at most, only an estimate of the degree of superiority is warranted from the averages at the bottom of this table.

TABLE V. Average composition* and energy content of samples of canned B.C. sockeye and pink salmon

Sample	Water %	Oil %	Solids %	Protein %	Salt-free mineral %	Salt %	Calories per pound
Sockeye:							
Skeena river							
range	61.8-70.5	7.7-15.5	20.8-24.1	....	....	..	...
average	66.7	10.6	22.7	20.1	1.3 (1.0)	1.0	819
Rivers inlet							
range	63.5-70.0	5.7-13.8	22.4-24.3	....	....	..	...
average	67.0	9.8	23.2	20.9	1.3 (0.9)	1.0	802
Fraser river (off mouth)							
range	62.9-71.1	6.5-14.8	20.8-23.0	....	....	..	...
average	67.3	10.4	22.4	20.4	1.4 (1.0)	0.7	819
Fraser river (up stream)							
range	65.8-72.4	4.2-12.7	21.5-23.4	....	....	..	...
average	69.2	8.5	22.8	19.1	1.4 (1.0)	1.4	712
Pink:							
Butedale							
range	68.0-71.5	5.0-8.9	22.4-23.6	....	....	..	...
average	69.9	6.9	23.2	20.6	1.6 (1.2)	0.8	674
Bones bay							
range	67.5-70.5	5.5-9.6	22.1-24.0	....	....	..	...
average	69.5	7.4	23.1	20.1	1.5 (1.1)	1.4	685
Fraser river							
range	72.2-79.4	2.5-5.9	20.2-21.9	....	....	..	...
average	75.9	4.0	20.6	18.2	1.3 (0.7)	1.0	507
Av. for sockeye	67.6	9.8	22.7	20.1	1.3 (1.0)	1.0	788
Av. for pink	71.6	6.1	22.3	19.6	1.4 (1.0)	1.0	622

*Reconstructed from data for individual components given in tables IV (*a*), (*b*) and (*c*). Averages for ash content in parentheses are calculated on a bone-free basis to facilitate comparison with data in table I. Averages for other constituents calculated on bone-free basis are not significantly altered from the above values.

SOLIDS

The percentages of solids were remarkably uniform, both as to range and species.

PROTEIN, MINERAL ASH, SALT, CALORIFIC VALUE

See discussion of table at bottom of page.

Table VI gives the percentage compositions of samples taken from a composite of six cans from each lot of salmon. These data are probably more typical of the different lots of cans than the data in table V since the analysis was more direct; but the ranges in table V indicate that the data in neither of these tables can be considered as more than roughly representing the compositions of the classes of fish from which the sample lots were secured.

WATER

In table VI the separate averages for percentage of water do not differentiate the sockeye from the pink salmon as sharply as in table V, but the averages for the species again indicate that in these canned samples the former species contained more water than the latter.

TABLE VI. Average composition of canned B.C. sockeye and pink salmon, from direct analysis of composite contents of six cans from each sample

Sample	Water %	Oil %	Solids %	Protein %	Salt-free mineral %	Salt %	Calories per pound
Sockeye:							
Skeena river	66.0	11.00	23.0	20.7	1.45	0.78	852
Rivers inlet	67.8	8.94	23.3	21.0	1.66	0.55	767
Fraser river (off mouth)	70.8	6.69	22.5	20.2	1.58	0.49	658
Fraser river (up stream)	70.0	8.67	21.3	19.0	1.59	1.39	719
Pink:							
Butedale	69.6	7.53	22.9	19.7	1.75	0.89	684
Bones bay	68.8	8.55	22.6	20.5	1.71	1.32	742
Fraser river	76.0	4.17	19.8	17.8	1.25	0.69	507
Av. for sockeye	68.6	8.82	22.5	20.2	1.57	0.80	749
Av. for pink	71.5	6.75	21.4	19.3	1.57	0.97	644

OIL

Considerable divergence between certain corresponding averages for percentage of oil in tables V and VI is evident. How much of this divergence was caused by experimental errors, or by variations in the averages for two corresponding six-can lots, cannot be ascertained. The use of petrol ether as oil solvent (table VI) instead of ethyl ether (table V) did not materially affect the results as preliminary experiments indicated that the petrol ether in one trial extracted 0.5% more oil and in another trial, 0.5% less oil, than the ethyl ether. The averages for the oil content of the two species lead to the same conclusion as in table V.

PROTEIN, MINERAL ASH, SALT

In both tables V and VI, these constituents are reported as percentages of the entire can content instead of on a dry basis as in tables IVa, b, c. The manner

in which the samples were combined before analysis precludes the insertion of ranges for these constituents in table V and as the data in both tables correspond very closely, they are here considered together. Similarly to the protein in the flesh (table IVa), the total percent of protein in these canned sockeye salmon was slightly greater than that in the pink salmon. Evidence of a slight decrease in protein content of the Fraser river sockeye samples persists in these two tables and in table IVa; the same applies to the Fraser river pink salmon samples if the high water content of the flesh (table IVa) is taken into account. The mineral ash contents in tables V and VI are very uniform with respect to both individual samples and species. Some discrepancy is observable between corresponding salt analyses in the two tables, those in table V being subject to criticism. The remarks made under "salt" in the last section apply to these data.

CALORIFIC VALUE

Since the calorific value per unit weight of oil is more than twice that of protein, discrepancies between corresponding percentages of oil in tables V and VI lead to similar discrepancies in corresponding calorific values in these two tables. The order in which the values for separate samples of each species fall is different in the two tables, and although the values in table VI are probably more accurate, they are nevertheless no more representative of the fish than are the values in table V. In both tables the averages for the species indicate that these samples of canned sockeye had a greater calorific value per pound than the pink salmon.

Emphasis must be placed on the statement that any attempt to assess comparative food values merely by indicating the proximate composition and calculated energy values, fails to take cognizance of the appearance and palatability of the product, the valuable specific properties of certain inorganic constituents, and the

TABLE VII. Average percentage* of total food values in can as individually

Sample	Flesh†			
	Oil	Prot.	Salt-free minerals	Calor.
Sockeye:				
Skeena river	85.3	95.3	61.9	89.8
Rivers inlet	86.5	95.9	57.0	91.2
Fraser river (off mouth)	89.3	95.4	60.4	92.2
Fraser river (up stream)	90.2	97.0	61.8	93.8
Pink:				
Butedale	78.7	95.6	69.0	88.4
Bones bay	80.4	95.2	68.1	88.6
Fraser river	88.5	95.0	45.1	93.0
Av. for sockeye	87.8	95.9	60.3	91.8
Av. for pink	82.5	95.3	60.7	90.0

*Separate percentages are averages for six individual cans.

vitamin content of the oil. Specialized proteins and digestion-promoting substances in the skin have been described by Komarov (1931). Each of these factors has a definite significance in the dietary value and falls outside the scope of this paper.

Loss of Food Value by Non-utilization of Entire Can Content (Tables VII, IX).

The method of analysis permitted some estimate of the contribution made by each component to the total content of the can. In view of the remarks made in the last paragraph, and the common practice of discarding certain portions when preparing canned salmon for the table, it is of interest to consider certain data as arranged in tables VII and IX.

Table VII shows that discarding the skin in these samples would have resulted in the loss of a considerable quantity of the oil, and quite appreciable amounts of the minerals and energy value contained in the can. Several investigators have shown that many of the most valuable inorganic constituents such as iodine (Lunde, Böe and Closs 1931) are concentrated in the skin of salmon. Discarding the bones would have caused a loss of almost one-third of the total mineral constituents.

Table IX presents the same type of data for the free liquids, and flesh exclusive of these liquids. Only average data for the two species are given, as only two representative analyses (table VIII) of the free liquor were made. Comparison of the percentages of oil and Calories lost in discarding the oil from these samples is interesting, as the low calorific loss from the pink salmon indicates that the oil as a whole was more firmly retained by the solids in the can. A considerable proportion of the protein and appreciable amounts of minerals in the can were contained in the free aqueous liquor, and in the event of the free oil and liquor being discarded, the average loss of total energy value in these cans of sockeye

contributed by the flesh,† skin, and bone in canned B.C. sockeye and pink salmon

Skin				Bone			
Oil	Prot.	Salt-free minerals	Calor.	Oil	Prot.	Salt-free minerals	Calor.
14.0	4.4	10.8	9.6	0.8	0.3	27.3	0.6
12.5	3.8	12.2	8.3	1.0	0.4	30.9	0.7
9.8	4.3	9.6	7.3	0.8	0.3	30.1	0.6
8.6	2.6	6.5	5.6	1.2	0.3	31.9	0.7
20.0	4.1	5.4	11.0	1.3	0.4	25.7	0.8
18.4	4.4	7.7	10.8	1.2	0.4	24.2	0.7
7.5	4.4	7.1	5.4	4.0	0.7	47.8	1.7
11.2	3.6	9.8	7.7	0.9	0.4	30.2	0.6
15.3	4.3	6.7	9.0	2.1	0.5	32.6	1.1

†Including free oil and aqueous liquor.

and pink salmon would have been 19% and 12%, respectively. The food value of the flesh as indicated in tables IV (a) and VII consequently would be decreased proportionally.

TABLE VIII. Average composition of free aqueous liquor from canned B.C. sockeye and pink salmon

Species	Water %	Protein %	Salt-free ash %	Salt %
Sockeye	84.2	13.31	0.72	2.54
Pink	85.1	12.23	0.60	3.07

TABLE IX. Approximate percentages of total food values in can as individually contributed by the free oil, aqueous liquor, and flesh* in canned B.C. sockeye and pink salmon

Species	Free oil		Free aqueous liquor			Flesh*			
	Oil	Calor.	Prot.	Salt-free minerals	Calor.	Oil	Prot.	Salt-free minerals	Calor.
Sockeye	26	15	11	5	4	62	85	55	73
Pink	10	4	14	7	8	72	81	54	78

*Exclusive of free oil and aqueous liquor.

CONCLUSION

The analyses of such samples of canned British Columbia sockeye and pink salmon as were used in this investigation (tables V, VI), when compared with samples canned in Alaska and Washington (table I), indicate that no definite conclusion can be drawn in regard to whether the British Columbia fish have a composition intermediate between the fish caught to the north and south. Considering the average calorific values for the two species in tables V or VI, the sockeye fits in fairly well between the specially-packed samples of south-eastern Alaska and Puget sound sockeye; no similar conclusion is valid for the pink salmon. Comparison of the same data in tables V or VI with the commercially-packed samples described in table I would indicate that the samples of Canadian fish had in general a lower calorific value, although the average for the commercially-packed American pink salmon was based on only nine cans.

Comparison of the separate average calorific values in tables V (or VI) and I, discloses a relation that further emphasizes the necessity of much more extensive sampling than was possible. In the analysis of the present samples, the northern salmon of both species had a greater calorific value per pound than the southern fish; the opposite was true when considering the corresponding species from Alaska and Puget sound. Factors contributing to the unreliability of the sampling have been discussed previously, and it is unwarrantable to make more detailed comparisons.

In general, the compositions of the present samples agree fairly well with those described in table I with the exception of the Fraser river pink salmon, which contained more moisture and less oil, protein, and energy content than any American pack of pink salmon.

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The Nutritive Value of Marine Products
IX. Proximate Analysis of British Columbia Canned Pilchard

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ABSTRACT

Proximate analyses of samples of canned pilchard from fish caught early and late in the season in one vicinity on the west coast of Vancouver island are tabulated. The average calorific value per pound of content was 747 and 1074 Calories, respectively. The percentage of fat (18.5) in the late-caught fish was almost twice as great as that in the early-caught fish. Separate proximate analyses of the flesh, skin, and bone disclosed significant changes in the percentages of fat, protein, and minerals in these components between the beginning and end of the season.

INTRODUCTION

The analyses of canned pilchard (*Sardinops caerulea*) reported in this paper were carried out during a period of summer investigation at the Pacific Biological Station, Nanaimo, B.C., as part of a programme of investigation into the nutritive value of British Columbia fishes.

The pilchard caught off the west coast of Vancouver island is generally recognized as the mature form of the California sardine, and creates an important fishery in the southern part of the province.

The only available reference of recent date to the proximate composition of the pilchard is contained in a comparative study by Dill (1926) who found the fat content of the Canadian fish to be considerably higher than that of the California sardine.

PROCEDURE

Sampling

Two cases of commercially canned pilchard, from fish caught early (July) and late (September) in the season were obtained from a cannery on the west coast of Vancouver island. Each case contained eight dozen "½-lb. flat" cans. Twelve cans were taken at random from each case to provide composite samples of the entire contents; three cans of the early fish and five cans of the late fish were also taken to provide samples of the separate components of the contents.

Preparation of Samples for Analysis

In general, the preparation of the samples for analysis was as described for the similar analyses of canned sockeye and pink salmon described by Carter (1936).

The entire content of each of the twelve-can samples was passed through a finely-set meat grinder and after thorough mixing as indicated by the uniform distribution of a small amount of added dye, two approximately 50-g. samples were removed from each composite for analysis.

A more detailed analysis was obtained by taking three cans of the early fish and five cans of the late fish and investigating each can separately. In each case the skin and all the bones were carefully separated from the flesh, which was then ground and thoroughly mixed with the previously-separated oil and aqueous liquor. The individual components were then analysed, wherever possible in duplicate or triplicate, and the results averaged.

Analysis

Analytical procedures followed were similar to those described by Carter (1936). Moisture was determined by drying the samples to constant weight *in vacuo* at 70°C., fat as the loss in weight of a dried sample after extraction with petroleum ether, nitrogen by Kjeldahl digestion of the extracted residue, and ash by incineration of an extracted sample in an electric muffle furnace. The halide content of the ash was determined by titration with silver nitrate and expressed as sodium chloride. The protein content was calculated from the determined nitrogen by means of the factor 6.25; calorific values were calculated from the fat, and protein contents by the usual factors of Rubner.

The data obtained from the proximate analyses of the entire contents are given in table I. Table II presents the proximate analyses of the separate components.

Table I. Average composition and calculated energy content of samples of canned B.C. pilchard

Sample	Water %	Fat %	Protein %	Sodium chloride-free ash %	Sodium chloride %	Total %	Calories per pound
Early caught	68.22	10.95	16.46	1.88	1.38	98.89	768
Late caught	60.70	18.88	15.85	1.64	1.52	98.59	1090
Average	64.46	14.92	16.16	1.76	1.45	.....	929

Table II. Average composition and calculated energy content of separate components in samples of canned B.C. pilchard

Component	Water %	Fat %	Protein %	Sodium chloride-free ash %	Total %	Calories per pound
Early caught:						
Flesh*	68.2	9.7	17.1	1.5	96.5	...
Skin	66.1	14.9	13.1	3.6	97.7	...
Bone	56.8	5.2	8.7	20.6	91.3	...
Total can content	68.0	9.8	16.9	1.9	96.6	726
Late caught:						
Flesh*	59.5	17.7	16.7	1.1	95.0	...
Skin	62.4	22.7	9.4	2.4	94.9	...
Bone	52.6	8.5	9.4	22.1	92.6	...
Total can content	60.0	18.1	15.7	1.5	95.3	1057

*Including free oil and aqueous liquor.

DISCUSSION OF DATA

The average net weights of content in the ½-lb. cans of early and late caught fish were 242 g. (8.5 oz.) and 254 g. (9.0 oz.) respectively. Contents weighing from 5.6% less to 14% more than one half pound were encountered.

The most striking feature of the analyses shown in table I is the considerable difference in percentage of fat in the two samples. Since the percentages of protein were practically the same, the difference in calorific values was due chiefly to the variation in fat content. Observation showed that the late caught samples, however, contained much more free oil than the early caught samples, and since much of this oil is frequently poured off before the contents of the can are utilized, the difference in the energy contents of the two lots of fish would tend to become less pronounced, as far as the consumer of canned pilchards is concerned. Dill reported that pilchards canned at Nootka in December 1922 contained 26.17% of fat as compared with a value of 20.66% for the Californian variety. This figure is considerably higher than the value now reported for fish canned in September, although the figures for protein and ash agree. The percentages of water and fat displayed a complementary relation in each sample, the sum of the two being about 79% in each case. Judging by the figures for ash content a small difference in mineral content appeared to be characteristic, as a similar difference is evident in the ash percentages for total can content in table II, determined from other sample cans. Sodium chloride is sometimes added to the fish in the canning process, hence the percentages of this constituent are not significant.

Table II gives the average percentage composition of the flesh, skin and bone in the samples. Owing to the separation of free oil and aqueous liquor in the can and its arbitrary inclusion with the flesh for analytical purposes, the proportional distribution of constituents shown in this and the following table is not strictly correct. Undoubtedly some of the oil and liquor was derived from the skin, but the percentage of skin in the can (table III) is so much less than that of the flesh, that the error of distribution is not great. It appears that the higher percentage of

TABLE III. Average percentages of total food values in can as individually contributed by the flesh,* skin, and bone in canned B.C. pilchard

Component	Total can content %	Total fat %	Total protein %	Total sodium chloride-free ash %	Total Calories %
Early caught:					
Flesh*	93.5	92.0	95.4	72.2	93.4
Skin	4.7	7.0	3.7	8.7	5.6
Bone	1.8	1.0	0.9	19.1	1.0
Late caught:					
Flesh*	87.2	85.0	92.4	63.0	87.1
Skin	11.5	14.4	6.8	18.1	12.3
Bone	1.3	0.6	0.8	18.9	0.6

*Including free oil and aqueous liquor.

fat shown for the late caught samples in table I was due chiefly to a greater oiliness of the flesh than of the skin. As the season advanced, the percentage of water in the flesh decreased, and the protein and mineral contents of the skin decreased as the amount (table III) of skin increased. In general, the percentage compositions and calorific values of the total content of samples shown in table II correspond quite closely with those in table I.

Table III was prepared from the data in table II to indicate the contributions made by the flesh, skin and bone to the total amounts of constituents in the can.

This table emphasizes certain features not brought out in table II; e.g., as compared with the skin of the early-caught fish, the skin of the late-caught fish contributed over twice as much of the total amount of minerals (ash) in the can, despite the lower percentage of ash in the latter.

CONCLUSION

As determined from analyses of both the total contents and separate components of the contents, the nutritive value in the sample cans of pilchards caught late in the season was much higher than that in the sample cans of fish taken early in the season. This difference was chiefly attributable to the higher fat content of the late-caught fish, as generally recognized in the commercial production of pilchard oil.

The nutritive value has been estimated by the calculated calorific value of the fat and protein, which does not take into account the vitamin content of the oil or the valuable properties of the minerals which are so readily assimilable in canned fish.

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The Nutritive Value of Marine Products
X. Proximate Analysis of Ling Cod

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ABSTRACT

Separate proximate analyses of the flesh and skin of three freshly-caught ling cod (*Ophiodon elongatus*) from the east coast of Vancouver island are reported. Average percentages of protein in the flesh and skin were 18.1 and 26.9 (moist) or 87.0 and 88.5 (dry); ash, 1.2 and 2.5 (moist); fat, negligible; Calories per 100 g. (moist), 81 and 117.

INTRODUCTION

In the course of an investigation into the food values of British Columbia fishes, carried out at the Pacific Biological Station, Nanaimo, B.C., the opportunity was afforded the author for carrying out certain analyses on freshly-caught ling cod (*Ophiodon elongatus*). Three fish were analysed, and the results are now reported.

TABLE I. Proximate analyses (mean values) and calculated energy values of the flesh and skin of ling cod

Sample	Proportion of whole fish %	Moisture %	Fat %	Protein %	Ash %	Total %	Calories per 100 g.
Flesh: (*a*)	49.0	78.5	0.8	18.6	1.2	99.3	...
(*b*)	49.7	78.9	0.6	18.6	1.4	99.5	...
(*c*)	51.7	80.2	0.6	17.1	1.1	99.0	...
Average.....	50.1	79.2	0.7	18.1	1.2	99.2	81
Skin: (*a*)	7.2	71.9	0.7	25.2	1.9	99.7	...
(*b*)	6.9	67.9	0.2	28.4	3.1	99.6	...
(*c*)	5.2	68.9	1.1	27.2	2.6	99.8	...
Average.....	6.4	69.6	0.7	26.9	2.5	99.7	117
Moisture-free basis							
Flesh (average)....	...	....	3.4	87.0	5.8	96.2	388
Skin (average).....	...	....	2.3	88.5	8.2	99.0	384

PROCEDURE

The three fish were all males, and weighed respectively 4.18, 1.5, and 3.5 kg. After being weighed, the head, viscera, and bones were removed and discarded as "waste". The skin was then carefully separated from the flesh, weighed, minced finely, and portions were set aside for analysis. Similarly the flesh was weighed, ground, mixed, and samples were analysed. The analytical procedures used were similar to those of Carter, 1936, and White, 1936, and need not be recapitulated. All analyses were carried out in duplicate or triplicate, the mean values being recorded in table I. In table II these results are presented on the basis of the whole fish.

TABLE II. Average composition of flesh and skin of ling cod, on the basis of the whole fish

Sample	Proportion of whole fish %	Moisture %	Fat %	Protein %	Ash %	Calories per 100 g.
Flesh	50.1	39.7	0.4	9.1	0.6	..
Skin	6.4	4.4	0.0	1.7	0.2	..
"Waste"	43.5	...	...	...	...	..
Total	100.0	44.1	0.4	10.8	0.8	48

DISCUSSION OF RESULTS

From these analyses it is evident that the nutritive value of the flesh of the ling cod is due to its protein content, the fat content being negligible.

It is interesting to note that weight for weight, the skin has a protein content roughly 50% greater than that of the flesh. That this is almost entirely due to the greater proportion of moisture in the flesh is evident from the lower part of table I, in which the constituents have been calculated on a moisture-free basis. Here the protein content of the dried flesh is shown to be almost as great as that of the dried skin.

It should also be noted that the protein content of the skin is mainly "scleroprotein", and therefore highly resistant to the action of the digestive enzymes, so that the true "food value" will be substantially less than is indicated by the calorific value. It has been shown by Komarov (1931), that for haddock, ingestion of skin broth brings about a marked increase in gastric secretion. Consequently the skin as a dietetic factor cannot be ignored.

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The Nutritive Value of Marine Products
XI. Proximate Analysis of Canned British Columbia Coho (Blueback) Salmon

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(*Received for publication April 28, 1936*)

ABSTRACT

Samples of canned coho (blueback) salmon (*Oncorhynchus kisutch*), from fish caught each month of the fishing season (May-September) in a limited area on the coast of British Columbia, were subjected to analysis from which nutritive values were determined by the calculation of calorific values. The average percentages of constituents in composite samples of the entire contents were: water, 72.8; fat, 4.50; protein, 19.9; sodium chloride-free ash, 1.37; sodium chloride, 1.13; calorific value per pound of contents, 562. Percentages of fat, protein, sodium chloride-free minerals, and consequently the food value, reached a maximum in cans containing fish caught in mid-July.

INTRODUCTION

The present paper deals with the analyses of monthly samples of canned coho (blueback) salmon (*Oncorhynchus kisutch*), performed in 1933 at the Pacific Biological Station, Nanaimo, B.C. Carter (1936) has pointed out briefly the reasons for undertaking an investigation of the composition and food value of salmon canned on the Pacific coast of Canada, and described the analysis of canned sockeye (*O. nerka*) and pink (*O. gorbuscha*) salmon.

No data on the composition or food value of coho salmon caught in Canadian waters have been published, although in various years coho salmon has ranked second or third in commercial value among the different species of salmon canned in British Columbia, the sockeye pack having the greatest value.

The fish were caught in the strait of Georgia and Johnstone strait. The early catch of coho begins in May and, in the northern part of the strait of Georgia, contains a large proportion of fish entering upon the third year of life and known locally as "blueback", under which name it is canned. The essential characteristic that distinguishes the blueback from the ordinary coho is the blue colour of the skin on the dorsal surface of the fish. Also, in the early part of the season the flesh of the former has a brighter pink colour than that of the latter, although as the season advances it is difficult to distinguish between the two. The blueback salmon from these waters are distinctly different from the American "blueback", the name given to sockeye salmon caught in the Columbia river region.

Previous Analysis of Canned Coho Salmon

The only analyses of canned coho salmon appearing in the literature are those of fish caught in Alaska, Washington, Oregon or California, such as reported by various authors including Loomis (1912) and Shostrom, Clough and Clark (1924). The last-named authors carried out an extensive investigation in which both commercial and specially-packed canned salmon from various localities were analyzed. Their data for coho salmon are summarized in table I.

Table I. Average composition of specially packed canned Alaska and Washington coho salmon. (Condensed from the data of Shostrom, Clough and Clark 1924)

Locality	No. fish analyzed	Bone %	Bone-free fish				
			Moisture %	Fat %	NaCl-free ash %	Protein %	Calories per pound
Alaska:							
Western alaska	27	1.67	66.57	10.31	1.22	20.83	822
Central alaska	36	1.95	68.94	6.74	1.25	21.61	686
SE. Alaska	18	2.06	68.01	7.80	1.28	21.50	728
Washington:							
Puget sound	9	2.19	65.43	8.95	1.20	20.46	758
Columbia river	9	2.39	65.41	11.33	1.22	19.35	838
Average	99	1.88	67.49	8.49	1.24	21.08	750

PROCEDURE

All procedures in sampling and analysis were essentially similar to those described by Carter (1936).

Sampling

Certain factors influencing the sampling of commercially canned salmon have been discussed by Carter (1936). In this programme, the variability of locality was probably eliminated since all samples were obtained from one cannery operating on blueback and coho salmon caught from the vicinity of Johnstone strait (50° 20′ N.). A twelve-pound sample in 1-lb. and ½-lb. cans was taken at random from the commercial pack of about the twentieth of each month from May to September inclusive. Samples for July, August and September were obtained from the 1933 pack but circumstances made it necessary to obtain the May and June samples from the previous year's pack. Although all samples were hand packed, the position of the sections of fish from which the cans were filled would vary from neck to tail with a consequent probable variation in the chemical composition as demonstrated in the spring salmon by Shostrom, Clough and Clark (1924).

Four 1-lb. and twelve ½-lb. cans were taken at random from the total samples and submitted to individual examination and analysis of the various components; six 1-lb. cans were taken from each monthly sample and a composite of their contents was sampled for proximate chemical analysis.

Examination of Individual Cans

The net weight of contents, degree of vacuum, and volumes of free oil and aqueous liquor were determined and table II summarizes the data obtained during the examination of four 1-lb. and twelve ½-lb. cans.

TABLE II. Summary of examination of samples of canned B.C. coho (blueback) salmon

Sample	Weight contents grams	Vacuum cm. Hg	Free oil ml.	Free aqueous liquor ml.
Four 1-lb. cans				
range	463-479	12-31	3-5	62-76
average	471	22	4	68
Twelve ½-lb. cans				
range	223-257	20-36	1-4	41-63
average	243	27	2.4	48

PREPARATION OF SAMPLES FOR ANALYSIS

SEPARATE COMPONENTS OF CAN CONTENT

The free oil, free aqueous liquor, flesh, skin, and bone in twelve ½-lb. cans taken at random from the total samples were separated as described in part VII under the preparation of individual samples. Instead of returning the free liquids to the flesh before analysis, however, the free oil plus aqueous liquor and the flesh were analyzed separately. In the analysis of canned pink and sockeye salmon, the flesh, skin, and bone in each sample were analyzed, and wide ranges in composition were found for these components in different cans. Once these ranges had been indicated it was considered unnecessary to repeat such detailed analysis and for the present investigation, the skin, flesh, bone, and free liquid separated from each can were combined to give composite samples of each component. The composite samples of flesh and skin were finely ground and each was thoroughly mixed. The total skin and bone, but aliquot portions of the flesh and free liquid, were used in the determination of water. The bones were ground and mixed after this determination.

TOTAL CAN CONTENT

The entire contents of six 1-lb. cans from each monthly sample were ground and thoroughly mixed. The thoroughness of the mixing was determined by the distribution of a small amount of added dye. Samples were then removed for analysis.

ANALYSIS

The various samples were analyzed for their content of water, ethyl ether extract ("oil"), solids, nitrogen, mineral ash, and sodium chloride and the protein and energy values calculated as described in part VII. The oil in the free liquid was determined by successive extractions with ethyl ether, which was then dried and evaporated, the residue being taken as the oil content. No difficulty was experienced in obtaining a white ash when the samples were

TABLE III. Average composition and energy content of separate components in samples of canned B.C. coho (blueback) salmon from May to September

Component	Water %	Fat %	Protein %	NaCl-free ash %	NaCl %	Total %
Flesh*	70.8	3.6	21.7	0.8	1.2	98.1
Skin	70.2	13.3	14.2	1.4	0.8	99.9
Bone	43.2	10.6	1.4	29.8	0.8	85.8
Free oil and liquor	80.3	4.1	17.4	0.6	2.5	104.8

*Exclusive of free oil and aqueous liquor.

burned at 550° to 600°C. The sodium chloride in this ash was in all cases determined by Volhard's method modified by boiling the precipitated chloride before back-titrating the excess of silver nitrate with ammonium thiocyanate.

Tables III and IV present the data obtained in the above analyses.

TABLE IV. Average composition and energy content of entire contents of monthly samples of canned B.C. coho (blueback) salmon

Date	Water %	Fat %	Solids %	Protein %	NaCl-free ash %	NaCl %	Total %	Calories per pound
May 1932	74.65	2.83	22.52	19.50	1.24	1.41	99.63	482
June 1932	74.17	3.35	22.48	19.04	1.03	1.70	99.29	496
June 1933	74.48	4.07	21.45	19.00	1.30	1.12	99.71	525
July 1933	69.75	6.83	23.42	21.01	1.67	0.48	99.91	679
Aug. 1933	71.53	5.25	23.22	20.55	1.08	1.67	100.08	604
Sept. 1933	72.04	4.65	23.31	20.79	1.91	0.41	99.80	584
Average..	72.77	4.50	22.72	19.89	1.37	1.13	.....	562

DISCUSSION OF DATA

EXAMINATION OF SAMPLES (TABLE II)

WEIGHT

The average weights of contents in the "½-lb." and "1-lb." cans were considerably greater than 227 g. (8 oz.) and 454 g. (16 oz.) respectively. In a later examination of all cans, the average weights of contents were 243 g. (8.6 oz.) and 477 g. (16.8 oz.); the maximum and minimum weights ranged from 13 per cent more to 1.7 per cent less than 8 oz. of contents.

VACUUM

Only one can examined contained a vacuum appreciably less than the 20 cm. (8 in.) recommended for prevention of loss of vacuum when cans are shipped to warm climates at high altitudes.

FREE OIL AND AQUEOUS LIQUOR

Considerable variations in the amounts of free liquids existed, the ½-lb. cans containing proportionately more than the 1-lb. cans. Clark, Clough, Fellers and Shostrom (1923) found the following average volumes in American-canned coho salmon (1-lb. cans): free oil, 4.8 ml. (range, 0.25 to 21 ml.); free liquor, 55 ml. (range, 23 to 92 ml.). Variations in the age of the samples after canning and the completeness of the drainage of these liquids makes comparison with any standard difficult.

COMPOSITION OF COMPONENTS (TABLE III)

The average composition and energy content of separate components in the samples is presented in table III. It will be noted that the total percentage for bone is rather low. This may be due to the loss of combined carbon dioxide occurring during the ashing of the mineral constituents, particularly those of the bone. The

slight deviations in the cases of other constituents are no doubt the result of using the factor 6.25 in converting the values for nitrogen into terms of protein, which is probably not exactly applicable to the proteins of fish (Jones 1931).

Composition of Entire Can Content (Table IV)

The data in table IV indicate that in general there was a noticeable variation in the composition of the samples from month to month. The variation is only as significant as the samples are representative of the fish caught in those months. However, in July, the percentages of fat, solids, protein, and sodium chloride-free minerals tend toward a maximum, and the percentages of water and sodium chloride tend toward a minimum. The calculated calorific value per pound follows the same trend as the fat and protein, as would be expected.

Estimation of the nutritive value by calculating the calorific content fails to assess the valuable mineral and vitamin content, and presupposes complete assimilation of the protein and oil. Holmes (1918) states that about 95 per cent of the oil and protein in canned salmon ingested by the human body is retained, and that the digestibility of this product is as great, if not greater, than that of most foods.

The sodium chloride content of both the separate components (table III) and total contents (table IV) has little significance, since this material is added during the canning process.

Food Value of Separate Components in Can (Table V)

Table V provides a means of estimating the loss in food value incurred by discarding any portion of the contents during utilization of a can of coho salmon. Discarding the oil and liquor that drains off in emptying the can involves a loss of over 18 per cent of the energy value of the contents and the skin of about 9 per cent. The proteins of the skin are not of particular significance, since some at least are indigestible. If only the flesh is utilized, over one-half of the minerals are lost, some of the most valuable of which are concentrated in the skin and bone.

Table V. Average percentages of total food values in can as individually contributed by the flesh, skin, bone, and free liquid in B.C. canned coho (blueback) salmon

Component	Total can content %	Total fat %	Total protein %	Total NaCl-free minerals %	Total Calories %
Flesh	71.3	58.1	77.5	42.4	70.9
Skin	6.1	18.5	4.4	6.0	9.1
Bone	1.9	4.5	0.1	41.8	1.6
Free oil and liquor	20.7	18.9	18.0	9.9	18.4

CONCLUSION

The nutritive value of these samples of canned coho (blueback) salmon appears to be greatest when the fish are caught in July. In respect to the average energy content (562 cal. per lb.) and mineral content (1.37 per cent) of all

samples, coho appear to be somewhat inferior to the samples of both pink and sockeye salmon for which the corresponding average values of 749 Cal., 1.57 per cent, and 644 Cal., 1.57 per cent, respectively, were found by Carter (1936).

Comparisons of data indicate that for the size and distribution of the samples analyzed, the Johnstone strait coho (blueback) salmon contained more water, less oil, and about the same amount of protein as coho caught in either northern (Alaska) or southern (Washington) waters. Decreasing the percentages of sodium chloride-free minerals in table IV by 0.4 allows an approximate comparison of these values with those of the bone-free samples in table I, and shows the former to be less than the latter except in July and September. The calorific values in table IV are all less than the lowest value given for any sample of Alaska or Washington coho sample in table I.

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The Nutritive Value of Marine Products
XII. Mineral Constituents of some Food Fishes of British Columbia

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ABSTRACT

Ashes of composite samples of canned sockeye, pink and blueback salmon and canned pilchard were analyzed for Ca, Mg, Na, Ka P. Cl, S and traces of Cu and Mn. Comparison of the relative amounts of these elements with their concentration in sea water indicates selective absorption of Ca and K over Mg and Na respectively. The presence of Cu and Mn in traces is important for dietetic purposes.

INTRODUCTION

In view of the considerable interest which has developed in recent years in the presence of inorganic materials in food stuffs, it seemed desirable to determine the mineral constituents of some of the commercial fishes of British Columbia. Accordingly the present investigation of the composition of the ash of composite samples of canned sockeye, pink and coho (blueback) salmon and canned pilchard was commenced. The following were chosen for determination: calcium, magnesium, potassium, sodium, phosphorus, chloride, sulphate, copper and manganese. There was involved the determination of satisfactory methods of analysis and a brief description of the procedures finally adopted are given.

Previous Work

Newell and McCollum (1931) examined the ash of seven species of fish spectroscopically and found that all contained calcium, iron, magnesium, phosphorus, potassium and sodium in considerable amounts. Aluminium, chromium, copper, lead, lithium, manganese and strontium were present as traces in all species, while fluorine, nickel, silver, tin, titanium and zinc were present as traces in some species and columbium and vanadium were doubtful.

The most complete analyses were carried out by Atwater (1892) for haddock and pike, the results of which are included with the results of the present investigation in table I. Albrecht (1921, 1932) has determined silicon, iron, calcium and magnesium for a number of marine molluscs and the occurrence of iodine has been investigated by Jarvis, Clough and Clark (1926).

Methods

In order to secure uniform samples for analysis, the contents of six tall tins were taken and finely ground. The liquor was added to the ground flesh, skin and bone and, after thorough

mixing, about a thousand grams were sampled out and charred in a porcelain dish over a hot plate. When the charring was complete the mass was ground in a mortar and again mixed. Most of the carbon was then burned off over a Bunsen burner, active combustion being carefully avoided throughout the process. The final ashing was carried out in a muffle furnace at 500° to 600°C. It was essential to prevent fusion of the ash as carbon particles were then included which proved very difficult to burn off.

When the sample had attained constant weight, the ash was ground in an agate mortar until it passed through bolting silk with 3,000 meshes per square inch. This material was heated again to drive off any moisture that had been adsorbed during the grinding.

CALCIUM, MAGNESIUM AND PHOSPHATE

Washburn and Shear (1932) have made a critical study of the gravimetric methods of determining calcium, magnesium and phosphate in bone ash. Since the greater part of the ash from fish is from bone, their method was considered to be applicable to the present investigation.

SULPHATE

The sulphate was determined by the usual gravimetric procedure, using the filtrate from the first phosphate precipitation as obtained by the Washburn and Shear method mentioned above. In carrying out these determinations it was found convenient to weigh out four half-gram samples for the calcium determination, which provided sufficient magnesium and sulphate for reasonable accuracy in their subsequent determination.

SODIUM

Sodium was determined by the uranyl acetate method according to the procedure given by Tabern and Shelberg (1931). A 0.05 gram sample containing 8 to 25 mg. of sodium, was digested for ten minutes with 5 ml. of water, and after decanting the clear liquid, the digestion was repeated with a similar quantity of water. The solution was filtered through a fine asbestos Gooch filter and the residue washed three times with 2 to 3 ml. of water. The combined filtrate and washings were evaporated to 5 ml. on a sand bath and analyzed for sodium by the method of Tabern and Shelberg.

POTASSIUM

For the determination of potassium the chloroplatinate method is the most desirable, but when a number of determinations are to be made it becomes expensive. Of the other methods the sodium cobaltinitrite method probably lends itself as well as any to routine determinations.

The analyses were carried out according to the suggestions of Van Rysselberge (1931) and the reagent was made according to Adie and Wood (1900). Several known and unknown solutions were analyzed at the same time under similar conditions.

CHLORIDE

The chlorides were determined volumetrically and, since there was difficulty in securing consistent results using the Mohr method, the Schoorl (1905) and Kolthoff (1917) modifications of the Volhard method were adopted. The reason for the difficulty with the Mohr method was apparently due to the high concentration of phosphate present in the ash. There was no sharp end point since silver phosphate is less soluble than the silver chromate, thereby causing a shading of colour as the end point was approached.

The sample was dissolved in dilute nitric acid, an excess of silver nitrate added and the precipitate coagulated by vigorous stirring or heating. After cooling the excess silver was titrated with standard ammonium thiocyanate to the end point, using ferric alum indicator. The mixture was vigorously stirred to remove the silver adsorbed on the surface of the precipitate, and the end point again approached by titrating carefully in the clear supernatant liquid.

COPPER

This element was present in traces and the very sensitive reagent sodium diethyl carbamate was applied to its analysis as described by Callan and Henderson (1929) and McFarlane (1932). With the exception of iron, interfering ions were present in low concentrations and did not have to be removed. The sample was dissolved in hydrochloric acid, the iron was oxidized with hydrogen peroxide and the solution made ammoniacal, precipitating the iron along with calcium phosphate. The solution was filtered and copper determined by the above methods.

MANGANESE

The most satisfactory method for determining small amounts of manganese is the recently developed method in which the manganese is oxidized to the permanganate by means of potassium periodate. In order to prevent the colour fading after it has been developed, it was necessary to remove all chlorides before oxidizing the manganese. The Richards (1930) modification of the method was applied to these analyses.

DISCUSSION

All determinations were carried out in duplicate or triplicate. Of the metals present in quantity, phosphorus and sulphur were reported as oxides, the chloride ion as such and manganese and copper as milligrams per gram of ash.

The results are shown in table I for Fraser river pink salmon, early and late Fraser river sockeye, and coho (blueback) salmon, and pilchard. The analyses of Atwater (1892) on haddock and pike are included in this table for comparison.

TABLE I. Percentage composition of ash of composite samples of various canned British Columbia food fishes

Species of fish	CaO	MgO	P_2O_5	SO_3	K_2O	Na_2O	Cl	Cu	Mn
	%	%	%	%	%	%	%	mg. per g. ash	
Fraser pink	10.71	2.05	23.91	1.18	19.78	20.05	18.42	.051	.009
Early Fraser sockeye	13.03	2.16	27.30	0.26	20.59	16.92	15.50	.070	.015
Late Fraser sockeye	14.79	2.30	30.00	0.70	21.62	12.54	9.80	.120	.000
Blueback	15.85	2.07	27.32	0.13	16.91	13.45	13.45	.034	.102
Pilchard	13.07	2.11	20.00	0.34	13.59	22.70	25.74	.0319	.034
Haddock*	3.39	1.90	13.70	0.31	13.84	36.51	38.10		
Pike*	7.38	3.81	38.16	2.50	23.92	20.45	4.74		

*From Atwater (1892).

The results indicate that these fish have a relatively high calcium and phosphate content which makes them valuable food during the period of bone formation. However, these analyses were carried out on composite samples containing the bone which would be expected to increase these values. Comparison of these values with those for haddock and pike shows a very much lower value of calcium for the latter but somewhat corresponding values for phosphorus.

Since salt is added to the fish during processing, some difficulty arises in reporting the sodium and chloride content of the ash. As this is a preliminary report on these analyses the total sodium and chloride were reported separately,

rather than as sodium chloride. It is interesting to note that, regardless of the added sodium chloride, the potassium content is of the same order of magnitude as the sodium, although present in a much lower concentration than sodium in sea water. This relationship exists for the fresh water fish represented by pike in the table.

Magnesium is present in uniform low concentrations in comparison with calcium, although it is present in higher concentration in sea water than calcium. This is an interesting case of selective absorption of calcium, which may have occurred in some organism that formed part of the fishes' diet.

Copper and manganese are present in traces, and in these quantities are valuable from the dietetic point of view.

The sulphate probably came mainly from the oxidation of sulphur containing proteins. Since the ashing was done by heat, it seems probable that a great deal of the sulphur may have escaped during the decomposition of the proteins during the charring. Experiments are under way to determine the distribution of sulphur in the tissues of fish.

SUMMARY

Canned sockeye, pink and coho (blueback) salmon, and pilchard have been analyzed for calcium, magnesium, sodium, potassium, copper, manganese, phosphorus, chlorine and sulphur.

The magnesium content is very uniform from species to species, but the other constituents show considerable variation. Calcium is present in higher concentration than magnesium although the latter is present in larger quantities in sea water. This selective absorption may have occurred with a previous organism. The potassium content is of the same order as sodium, while the sodium content of sea water is much higher than potassium.

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The Nutritive Value of Marine Products
XIII. Mineral Constituents of the Flesh, Skin, Bone and Free Liquor in Canned British Columbia Coho (Blueback) Salmon

By W. A. Riddell
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ABSTRACT

Determinations of the Ca, Mg, Na, K, P and Cl content were made and the ratios of calcium, magnesium and phosphorus oxides suggest the presence of calcium and magnesium metaphosphates in the ash of the flesh, calcium metaphosphate in that from the skin and tribasic calcium orthophosphate in that from the bone.

INTRODUCTION

The analyses of the mineral ash from the total can content in samples of several species of canned British Columbia food fishes were described by Riddell (1936b). These analyses have now been extended by the separate examination of the ash from the flesh, skin, bone and free oil and aqueous liquor in one of the products, namely, canned coho (blueback) salmon (*Oncorhynchus kisutch*).

PROCEDURE

The remainders of the materials prepared during the proximate analysis of the separate components in canned coho salmon described by Riddell (1936a) were used in the present analyses. These samples were first charred by heat and finally ignited in a muffle furnace until a white ash of constant weight was secured.

The methods of analysis were selected from those described by Riddell (1936b).

Table I presents the results of these analyses.

Table I. Percentage composition of the ash from the composite samples of the skin, bone, flesh, and free liquids in canned B.C. coho (blueback) salmon

Component	CaO %	MgO %	Na_2O %	K_2O %	P_2O_5 %	Cl %	Total %
Skin	13.51	2.40	9.18	17.15	33.31	21.22	96.77
Bone	47.13	3.37	0.14	1.27	38.48	1.68	91.17
Flesh	5.30	2.03	18.09	15.75	23.41	33.85	98.43
Free liquids	0.65	1.86	13.76	25.39	18.65	48.18	108.49

DISCUSSION

It is evident from table I that calcium and phosphorus are concentrated in the skin and bone, while calcium is very low in the liquor as would be expected from the low solubility of calcium phosphate and the high value of the dissolved phosphate. The high values for potassium found in the skin, flesh and liquor indicate a considerable concentration of this element in the tissues, while the magnesium is fairly uniform throughout all samples.

The analyses do not total 100 per cent since first, they do not include all the elements present, and second, although the method of reporting the results is suitable for such materials as bone ash where the elements are combined in oxygen compounds, it may not be suitable for the ash from the liquor where it is probable that only a small fraction of the sodium and potassium is found in oxygen compounds. Thus, reporting the sodium and potassium as oxides will introduce an error in the case of the liquor, but the method of reporting was retained for uniformity.

The average amounts of skin, bone, flesh and liquor in the cans were found to be respectively 6.13, 1.88, 71.31 and 20.68 per cent of the total can content (Riddell 1936a). From these data and those presented in table I it is possible to calculate the percentages of the total amount of each mineral constituent individually contributed by the skin, bone, flesh and liquids. The results of this calculation are shown in table II.

TABLE II. Percentages of total mineral constituents supplied by the skin, bone, flesh, and free liquids in canned B.C. coho (blueback) salmon

Component	CaO %	MgO %	Na_2O %	K_2O %	P_2O_5 %	Cl %	Total ash %
Skin	14.7	7.2	3.4	3.0	8.8	3.7	5.93
Bone	15.8	3.1	0.0	0.0	3.1	0.1	1.73
Flesh	67.1	70.7	79.0	64.0	71.5	68.1	70.16
Free liquids	2.4	18.9	17.5	29.9	16.5	28.1	22.44

When the percentages from table I are calculated on the basis of molal composition the results shown in table III are obtained. From these data it is seen that the calcium and phosphorus in the ash of the skin are present in the ratio that suggests the presence of $CaO.P_2O_5$ ($Ca(PO_3)_2$ or calcium metaphosphate). This compound very probably arose by the loss of water from the monobasic calcium orthophosphate, $Ca(H_2PO_4)_2$, during the ignition of the ash. Similarly in the flesh ash the metaphosphates of calcium and magnesium are indicated as probably arising in a similar manner. The results of the analysis of bone ash strongly suggest that $3CaO.P_2O_5$ ($Ca_3(PO_4)_2$, or tribasic calcium orthophosphate) is present (cf. Klement et al. 1929, 1932, and Marek, Wellmann and Urbányi 1935).

These analyses show further that there is an excess of calcium and magnesium over that required for the formation of the corresponding phosphates. Since there is no more chloride than is necessary for the sodium, potassium and part of the

TABLE III. Molal composition of the ash of the skin, bone, flesh, and free liquids of canned B.C. coho (blueback) salmon

Component	CaO	MgO	Na_2O	K_2O	P_2O_5	Cl
	concentration in moles per 100 g. of ash					
Skin	0.242	0.06	0.148	0.182	0.231	0.596
Bone	0.842	0.086	0.0023	0.0136	0.27	0.047
Flesh	0.095	0.05	0.29	0.168	0.162	0.954
Free liquids	0.01	0.047	0.22	0.27	0.13	1.38

magnesium, some at least of the calcium and magnesium must have been present in the ash as oxides. These were probably present as carbonates in the original bone, and as such would lose carbon dioxide during the ashing to produce the oxides.

Although the total bases present in the bone are somewhat too low for complete agreement, these findings do agree in general with the findings of other workers, who consider that the bone salts occur in variations of the apatite type, $CaX_2.3Ca_3(PO_4)_3$, where X_2 may be CO_3, $(OH)_2$, F_2, O or SO_4, (Klement et al. 1929, 1932; Marek, Wellmann and Urbányi 1935; Roseberry, Hastings and Morse 1931; Taylor and Sheard 1929).

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The Nutritive Value of Marine Products
XIV. Proximate Analyses of Fresh British Columbia Oysters

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ABSTRACT

Proximate analyses were made at bi-monthly intervals during 1933-34 on samples of *Ostrea lurida, O. virginica,* and *O. gigas* grown under identical conditions in the strait of Georgia. The proportions of glycogen and protein are shown to be approximately reciprocal and the greatest variation to occur during the summer. The energy content varies slightly, attaining a maximum in late fall and early winter, *O. gigas* having the highest and *O. lurida* the lowest values.

Three species of oysters now occur in British Columbia waters, namely, *Ostrea lurida,* native to the coast, *O. virginica,* imported as adults from the Atlantic seaboard, and *O. gigas,* imported as seed from Japan. The culture of these species is almost wholly confined to the strait of Georgia where the high concentration of dissolved nutrient salts (Lucas 1929), high surface temperatures, and low chlorinities are favourable for an abundant production of phytoplankton (Hutchinson and Lucas 1931).

This research, conducted in 1933-34, was designed to indicate the variations in chemical composition with regard to moisture, protein, glycogen, fat, and ash, at bi-monthly intervals between these three species when grown under identical conditions, so that the seasonal variations in food value might be determined.

The early investigations discuss glycogen only. Russell (1923), reviewing the monthly analyses of *O. edulis* taken from four localities in England, is the first to consider a series of complete analyses over a period of twelve months. In his study, fifty oysters were taken as a sample, and of these ten were analysed for glycogen, the remainder being used for the determination of moisture, protein, fat and ash.

PROCEDURE

Quantities of the three species under consideration, sufficient to supply the needs of the investigation, were gathered at random from the commercial beds around the strait of Georgia, placed on a small bed (four metres square) in Ladysmith harbour (latitude 49° 01′ N., longitude 123° 50′ W.), and allowed six months' time to become acclimatized.

The samples consisting of 50 to 60 *O. virginica* and 48 to 55 *O. gigas* were counted at the time of each analysis. *O. lurida* was measured by volume, one litre of the meats and liquor ("solid pack") being taken. There were between four and five hundred individuals in each sample, the number varying with the physical condition of the oysters.

The selected oysters were gathered at random, immediately shucked, washed in fresn water, the excess moisture absorbed in paper towels, and the weight of this total moist sample taken. This is essentially the same procedure as cited by Russell. Later investigation showed that there is a significant loss of chemical constituents when the liquor in the shells is wasted. Consequently, the whole of the contents of the shell should be used for analyses.

The meats were finely minced, thoroughly mixed and sampled in duplicate, 50 grams for the glycogen determination and 75 grams for the general analyses.

Pflüger's method with the modifications of Cori and Cori (1933) and Good, Kramer and Somogyi (1933) was used for the preparation and hydrolysis of glycogen. The resulting glucose solution was determined by the Schaffer-Hartmann cuprous method (1921) with the modifications of Marsh and Joselyn (1932) and Schaffer and Somogyi (1933). Glucose was determined from the copper factor by Munson and Walker sugar tables and multiplied by Pflüger's glycogen factor, 0.927.

Glycogen was determined on the fresh sample and later calculated on the basis of dry weight. The moisture determinations on the separate duplicate samples never differed by more than 0.7 per cent, but this could introduce a variation of 3.5 per cent in the glycogen determination.

Russell and co-workers express the discrepancy between the total analysis and 100 per cent as carbohydrates other than glycogen. They assume that all the carbohydrate is present as glycogen in the fresh oyster, but that during the preparation for analysis some of this becomes hydrolysed and (presumably) the resultant products are destroyed in the alkali digestion or are not precipitated by alcohol.

The moist sample for proximate analyses was dried to constant weight at 60°C. and 15 mm. pressure, and the loss of weight recorded as moisture. If the sample was dried at 100°C. in the customary manner there was evidence of caramelization and a resultant loss of carbohydrates which did not occur with the procedure cited.

The duplicates from the drying were mixed, ground fine, and sampled in duplicate for the determination of nitrogen and fat. Nitrogen was determined by the Kjeldahl-Gunning-Arnold method on the macro-scale, and the factor 6.25 was used to convert the values obtained to terms of protein. The use of this factor is arbitrary and open to much criticism. Rosedale and Morris (1930) have shown that the proportions of the various amino groups in the oyster are not the same as in mammalia, on which the factor 6.25 is based. Malcolm (1927) shows that the proportion of non-protein nitrogen is relatively large and Field (1909) states that some of this appears to be incorporated with the lipoids and so is included twice in the proximate analyses.

Fat was determined as the loss of weight from the dried sample after 36 hours' continuous extraction with dry petroleum ether in a standard soxhlet apparatus. It was found that a minimum of 30 hours was necessary to obtain constant weight with this medium.

Petroleum ether was substituted for ethyl ether after investigating the weight of oil extracted by both media. It was found that the ethyl ether extract was 4.60 per cent greater than the petroleum ether extract on the same material and that this difference was constant during several observations made at different times of the year. The petroleum ether has no tendency to absorb water vapor from the air and otherwise is very convenient to use, and since no analysis of the oil was to be made, it was used throughout the series. The results were adjusted for the difference between the two media and are reported as ethyl ether extract so that they may be compared directly with those cited in the literature.

The residues from the duplicate extractions were mixed, re-ground, and sampled in triplicate. The ash was determined on these as the residue after complete incineration in a porcelain crucible at dull red heat in an electric muffle (Mitchell 1917). The values for mineral ash include sodium chloride.

CHEMICAL COMPOSITION

Table I shows the chemical composition of the three species of oysters during the period of the investigation.

TABLE I. Chemical composition of B.C. oysters

Date	Average weight (grams)	Moisture	Solids calculated on moisture-free flesh				Discrepancy (from 100% analysis
			Protein	Glycogen	Fat	Ash	
		%	%	%	%	%	
			O. lurida				
Feb. 9	....	80.9	49.4	24.2	6.75	8.36	11.29
Apr. 12	....	81.50	45.55	17.57	10.23	12.28	10.37
May 30	....	79.90	57.90	13.26	11.24	8.67	9.93
Aug. 3	....	80.97	43.2	22.60	10.13	8.90	15.37
Oct. 3	....	80.40	49.70	17.65	8.65	7.20	16.85
Dec. 7	....	81.36	50.7	21.68	12.30	6.31	9.01
Feb. 6	....	79.00	49.8	19.05	13.30	6.35	11.50
			O. virginica				
Feb. 9	9.50	78.1	41.71	28.23	8.45	7.22	14.39
Apr. 12	7.24	81.78	45.55	29.45	11.51	7.29	6.20
May 30	11.08	76.20	51.40	19.46	9.38	8.17	11.59
Aug. 3	7.43	82.14	49.00	16.30	12.13	12.66	9.91
Oct. 3	6.39	81.25	50.50	15.51	8.56	6.99	18.44
Dec. 7	7.70	83.80	51.60	19.20	10.92	8.38	9.90
Feb. 6	8.42	81.66	51.20	19.32	13.09	6.22	10.17
			O. gigas				
Feb. 9	18.90	78.20	47.80	20.5	10.68	8.66	12.36
Apr. 12	18.30	79.84	46.65	24.95	12.94	7.62	7.84
May 30	16.72	77.50	45.7	23.80	13.31	6.87	10.32
Aug. 3	11.07	81.41	54.6	11.85	15.75	7.80	10.00
Oct. 3	17.40	80.00	52.2	14.25	11.72	5.78	16.05
Dec. 7	20.10	83.37	49.0	20.05	13.08	8.42	9.45
Feb. 6	20.00	79.89	49.6	19.00	15.27	6.81	9.32

Due to the fact that the oysters were washed and blotted before weighing, the moisture content in these analyses cannot be taken as significant. The dry weight is used as the basis of comparison in all cases.

It will be seen by reference to the table that the concentrations of the various constituents are of the same order in all of the three species, but the characteristics of variation differ somewhat. Such differences are to be expected if the habits of the species are considered. According to Elsey (1933) the hermaphroditic species, *O. lurida,* has a spawning season extending usually from early in May to the end of August. During the entire period, a portion of the oyster population is in a spawning condition, but there are peaks in the curve of seasonal spawning activity.

In the year under consideration one of these occurred between May 25 and June 5 and another early in August. These are marked clearly in the analyses by high values in the percentage of protein and low in the proportion of glycogen, particularly at the time of the major spawning effort in the spring. The analysis of May 30 was made shortly before the spring spawning while that in October was made after the oysters had partly recovered from the fall spawning.

Russell's discussion of oysters from Whitstable shows very similar seasonal variations in these two factors, the peaks on the curve showing approximately the same range of variation and at the same time.

O. virginica spawns only in exceptionally warm seasons in British Columbia, the adults being placed on beds as a means of preserving them for the fresh market. They usually lose weight more or less continuously and live more than two years in only a few of the most favourable locations. Table II shows this species to have gained weight in May and to have lost steadily till the end of the summer when there was very slight increase as winter set in.

The relationship of the protein and glycogen proportions is reciprocal as in the other species, but there are no sharp peaks as in the development of *O. lurida.* The protein percentage increased in the spring while the glycogen proportion decreased and both remained fairly constant throughout the summer. During this year spawn was developed but not shed. In the late fall the glycogen proportion increased slightly as the protein decreased.

The seasonal variation in this species is more like that observed by Malcolm (1928) in New Zealand than that in the British oysters as observed by Russell or in the Japanese as studied by Sekine *et al.* (1929) and Masumoto *et al.* (1934).

Spawn usually develops in *O. gigas* about the middle of June and is either released between late July and early September or retained and absorbed in the winter. When midsummer spawning occurs, the oysters are fully recovered and have a high proportion of glycogen by the middle of November. When spawning fails to occur, the recovery is often delayed until December or January. In the summer of 1933 a considerable proportion of the oysters in Ladysmith harbour spawned between August 1 and 10. Another spawning occurred at the end of August, but there were many oysters which retained their spawn throughout the season. There is good evidence that only a few of the oysters on the experimental flat spawned. Although they experienced a very definite loss in weight between May 30 and August 3, most of them did not have, at any time, the thin watery appearance of completely spent oysters.

The table shows an increase in protein and a characteristic decrease in glycogen between May 30 and August 3. By October 3, protein values had dropped slightly and glycogen values increased. On December 7, protein was still lower, whereas a large increase in glycogen had occurred. The glycogen values, however, are still less than those of April, which is the month in which *O. gigas* is usually in the finest market condition.

The Japanese workers are the only authors who found the development of oysters similar to these. The peak of protein development and glycogen loss occurs in the late summer in these oysters which differentiates them from the Atlantic

species, and in the comparison of seasonal development this fact should be kept constantly in mind.

When the percentage composition of the oysters is considered without reference to the body weights, there appears to be direct evidence of an increase of protein content at the expense of glycogen as the spawning season approaches. In the case of *O. lurida* and *O. gigas* in particular the two curves are approximate reciprocals.

The work of Malcolm (1928) does not show this very clearly and he does not recognize any significant change in the protein proportion throughout the year. The work of Sekine is more definite although no relationship is recognized, but the findings of Russell and Masumoto *et al.* are almost identical with those of this investigation.

Russell indicates that the variations in total carbohydrates are opposite to those of the proteins and suggests with reference to Pekelharing that the glycogen is used to supply materials, by the transformation to protein, for the development of the spawn, and referring to Hoek that it may also be used for metabolism in cold weather.

The average dry weight of *O. virginica* was less at the end of the year than at the beginning, but in view of the history of this species in these waters this loss was expected. The gain in weight of *O. gigas* was not as great as expected and this may be due to several causes, but it is probably an indication that the sample was too small. However, since the weights of the various constituents are relative to the dry weight, they can be considered in any case.

It will be seen that the maximum weight occurred in the winter and was followed by a loss of weight in the early spring months. Oceanographical investigations of the waters of the region have shown that the phytoplankton population and the temperatures reach a minimum in late February and early March, and it is probable that the spring loss of weight is due to the lessened activity and food supply during this period. The fact that this loss is more conspicuous in *O. virginica* than in *O. gigas* may be explained on the findings of Galtsoff (1928), who has shown that *O. virginica* stops feeding when the water temperatures fall to 5°C., and of Elsey, who has found that *O. gigas* feeds very slowly at 0°C. (private communication).

Russell suggests that stored glycogen is used for metabolism during this period of arrested activity, but it is shown here that the loss of weight is divided between the major constituents, rather more weight being lost from the protein than from the glycogen, indicating that it is not used specifically at this time.

The Japanese oysters observed by Sekine *et al.* and Masumoto *et al.* do not show this winter loss in weight, probably because feeding was not arrested to the same extent in Japan.

The fact that oysters lose weight in the summer after spawning agrees with the findings of Russell, Sekine *et al.*, and Masumoto *et al.* It is realized that the actual spawning of the oysters occurs within a few hours time, but the recovery of the weight lost during the act requires several months as shown by the authors cited, and it is evident that on a sample of fifty individuals the bi-monthly analyses

undertaken here would show distinct effects of the spawning loss and may be considered indicative of the annual growth of the oysters.

Before spawning, *O. gigas* increased slightly and *O. virginica* increased greatly in weight. In both cases the glycogen proportion varied reciprocally with the protein percentage, which increased as the spawning period approached.

The loss of weight at spawning includes both protein and glycogen, but proportionately the loss of glycogen is greater than that of protein so that the variations are approximately reciprocal.

Russell's Burnham oysters show a distinct loss of weight in the spring similar to that observed in *O. virginica* and less distinctly in *O. gigas*. The glycogen and protein proportions vary reciprocally. The Kusatsu oysters do not show the spring loss in weight noticeable in the English and Canadian varieties, but the proportions of protein and glycogen vary reciprocally with each other during the spawning period.

The variation in fat and ash content varies as much as 100 per cent during the year but the proportion of these constituents is so small that the fluctuations are not significant except when considering energy content. The fat and ash show a slight tendency to increase as the spawn develops, which may bear some relationship to the fat content of the spawn (Masumoto *et al.* 1932) and the increase in shell building activity during the summer.

FOOD VALUE

The energy content of these oysters was calculated from Rubner's tables (1901) in terms of calories, protein being equivalent to 4.1, glycogen to 4.1 and fat to 9.3 calories per gram. Table II shows the energy content of 100 grams of fresh oyster meat.

Amongst these species, *O. gigas* has definitely the highest energy content.

The major variations in calorific value per unit weight can in most instances be traced to variations in the proportions of fat, which becomes particularly significant in this regard due to its great energy content. It is noticeable that the loss of energy at spawning time is not as great as would be expected from a cursory examination of the analyses. As the proportion of glycogen becomes less, the fats and proteins increase, and the resultant heat value is very nearly constant.

Russell (1923) shows that for *O. edulis* in Great Britain the season of greatest energy content is in late fall, whereas the present investigation indicates that for *O. lurida, O. virginica* and *O. gigas* in British Columbia there is a tendency for the highest values to occur in late winter and early spring.

Atwater (1884, 1892) classes oysters very low, with cod and flounders, in scale of heat-giving foods, and Clark and Clough (1926) show that they have the least energy value of any of the sea foods, raw, cooked or preserved. McCollum (1926) suggests that oysters serve as a vegetable in the diet, rather than a flesh food, due to the high content of carbohydrate and nutritive salts.

The presence of considerable amounts of glycogen in oysters is somewhat unusual among foods but is of no particular significance from the viewpoint of

TABLE II. Energy content of British Columbia oysters

Sample	Calories per 100 grams of fresh oyster meat			
	Protein	Glycogen	Fat	Total
		O. lurida		
Feb. 9	38.6	19.0	12.0	69.0
Apr. 12	37.6	13.4	17.6	68.5
May 30	47.6	10.9	21.0	79.5
Aug. 3	33.7	17.6	17.9	69.2
Oct. 3	40.0	14.2	15.8	70.0
Dec. 7	38.8	16.5	21.3	76.7
Feb. 6	42.9	16.4	26.0	85.3
		O. virginica		
Feb. 9	37.6	24.5	17.2	79.3
Apr. 12	34.0	22.1	19.6	76.7
May 30	50.2	19.0	20.8	90.0
Aug. 3	35.7	11.9	20.1	67.7
Oct. 3	38.8	11.9	14.9	65.6
Dec. 7	34.3	12.8	16.4	63.5
Feb. 6	38.6	14.5	22.3	75.4
		O. gigas		
Feb. 9	42.7	18.3	23.4	84.4
Apr. 12	38.4	20.6	24.2	83.2
May 30	42.0	21.8	27.9	91.7
Aug. 3	41.6	9.0	27.2	77.8
Oct. 3	42.9	11.6	21.8	76.3
Dec. 7	33.4	14.9	20.2	68.5
Feb. 6	40.9	15.7	28.8	85.4

nutrition. Other sources of carbohydrates are plentiful and glycogen has been placed last in a series illustrating the relative nutritive values of different carbohydrates (Ariyama and Takahashi 1929). The glycogen content of oysters is interesting, chiefly because of its great seasonal variation, which gives rise to considerable modification in the appearance and palatability of the mollusk, particularly during the spawning period.

CONCLUSIONS

It is apparent that the food value of the oysters in terms of available energy shows very little seasonal variation. There are, however, marked seasonal variations in the glycogen and protein values which are definitely associated with the sexual conditions of the oysters. The variation in glycogen is important from a food standpoint since there is a positive correlation between flavour and glycogen content.

On the basis of these analyses it may be considered that *O. lurida* is in best

marketable condition from late October to the middle of April; *O. virginica* from the middle of September to the middle of May; and *O. gigas* from the middle of November to the beginning of June.

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The Influence of Temperature, Salinity, Light and Food Conditions on the Survival and Growth of the Larvae of the Lobster (*Homarus americanus*)

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ABSTRACT

At 24°C. lobster larvae attained the fourth stage 10½ days after hatching, at 19°C. in 13½ days, at 14°C. in 26½ days, at 10°C. in 54½ days, and at 6.7°C. in 120 days. Larvae were reared to the fourth stage at all salinities between 18 and 35 per mille, salinities even as low as 21 per mille being only slightly less favourable to survival than the normal 31 per mille. Larvae reared in almost complete darkness had a higher survival rate, moulted to the fourth stage 3 or 4 days earlier, and were significantly larger in the fourth stage than similar larvae reared in the light of a northwest window. Cutting down the supply of plankton food lengthened the stage periods and lessened the chances of survival.

INTRODUCTION

On the lobster fishing grounds of the Maritime provinces many variations in physical conditions are known to exist. The most unprotected part of the life-history of the lobster is during the early free swimming larval period. Since in nature there must be a tremendous mortality among larval lobsters, our experiments were directed toward discovering how variation in certain environmental factors led to a large percentage survival of lobster larvae in certain regions and a small percentage survival in others. Experiments were planned to show the effects of different temperature, salinity, light and food conditions on the survival and growth of lobster larvae. These factors must be considered in any evaluation of natural reproduction or of schemes for artificial rearing.

In the first three stages the lobster is free swimming and does not retreat from danger and seemingly has no awareness nor fear of enemies. The fourth stage, however, has assumed definitely the lobster shape, and by rapid movements attempts to escape from an enemy.

Although well suited to bottom life, this stage actually has been caught even more often at the surface than the earlier stages (Herrick 1911). However, as the fourth moult approaches, the animal spends more and more time on the bottom, seeking hiding places and hiding from the daylight. Toward the end of the fourth stage and in the fifth stage the bottom-seeking tendencies and hiding

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and shunning the light become more and more pronounced. For these reasons in the present paper the larval life is considered to end with the attainment of the fourth stage, and the experiments have merely been concerned with larval life from hatching to the fourth and occasionally to the fifth stages.

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METHODS

The only feasible method of controlling temperature, salinity or food lay in the use of still water in glass containers. Best jars, 6 inches (15 cm.) high and $3\frac{1}{4}$ inches (8 cm.) diameter, were used, with about 250 cc. of sea water. The sea water used was obtained from the end of the Atlantic Biological Station wharf and varied in salinity between 30 and 32 per mille during the course of the experiments.

All larvae used in any particular experiment were hatched at the same time from the same lobster. The first stage larvae were transferred to the experimental conditions within a few hours after hatching. Preliminary experiments showed that clam gonad, the first stage larvae themselves and live copepod plankton were suitable as food. The best results were obtained by using plankton and consequently in the experiments to be described the food consisted of live plankton, chiefly the small copepods common near the station wharf—*Acartia*, *Tortanus*, *Eurytemora*, *Pseudocalanus*, etc. Only one larva was placed in each bottle. Only one factor of the four—temperature, salinity, light and food was allowed to vary in any particular experiment, the remaining factors being the same for all larvae in the experiment, the times of changing water and the amount of water used also being the same throughout any particular experiment. At temperatures below 17°C. changing the water once every three days was found to be satisfactory, while at higher temperatures up to 20°C. the water was changed every second day, and above 20°C., every day. The plankton food was added immediately after changing the water. The increase in salinity of the water in these bottles in two days at 20°C. amounted to only 0.1 per mille. In the experiments with a relatively constant temperature varying not more than one degree during the day, the temperature was taken daily at irregular hours. Experiments with more variable temperatures were checked morning and afternoon usually at 9.00 a.m. and 5.00 p.m.

TEMPERATURE

Figure 1 shows the length of time required at different temperatures for lobsters to complete the various stages of their free swimming larval period, the salinity and food conditions in the experiments being normal, and the larvae kept either in darkness or in very dim light such as an ordinary electric light.

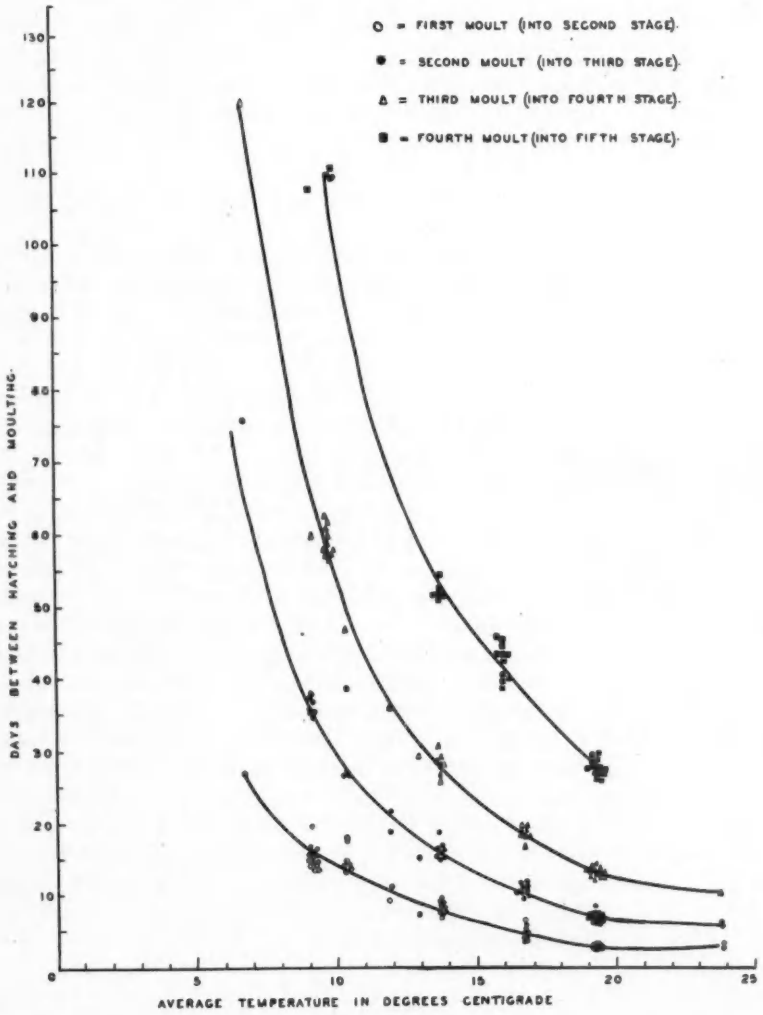

FIGURE 1. Length of time between hatching and the moulting of lobster larvae into second, third, fourth and fifth stages at different temperatures.

Average daily temperatures are used and corresponding with these averages the temperature ranges throughout the course of the various experiments were as follows (the temperatures in degrees Centigrade):—

Aver. temp.	Range	Aver. temp.	Range	Aver. temp.	Range
6.7	5.0– 8.6	10.3	9.4–11.3	13.7	12.9–15.2
9.1	8.0–10.0	11.9	11.4–12.2	16.7	15.9–18.0
9.9	9.1–10.9	12.9	12.5–13.4	19.2	19.0–19.6
				23.8	23.6–24.2

Before changing water the new water was always heated or cooled to the temperature required in the experiment.

At 24°C. the lobster reached the fourth stage in 10½ days after hatching; at 19°C., in 13½ days; at 14°C., in 26½ days; at 10°C., in 54½ days; and at 6.7°C., in 120 days. At all temperatures above 9°C. the larvae were reared at approximately the same temperature from hatching to the fourth stage. At 6.7°C., however, larvae immediately after hatching and others immediately after moulting into the second and third stages at higher temperatures were transferred to a temperature range from 5.0° to 8.6°C. (average 6.7°C.) and allowed to moult into the next succeeding stage at this temperature. At 19°C. the fifth stage, marking in most cases the end of the free swimming larval period, was attained in 28 days after hatching; at 14°C. in 50 days; and at 10°C. in 100 days.

Hadley (1906) reports the effects of temperature on the length of the larval period in lobsters reared in quantity at Wickford, R.I., and at Woods Hole. The larvae at Wickford were kept in scrim bags in the harbour and fed on small particles of clam. Here at an average daily temperature of 22.2°C. the fourth stage was attained in 11 days after hatching, and with an average temperature of 18.3°C. in 16 days; while at Woods Hole with an average daily water temperature of 15.6°C. the larvae required 23.5 days after hatching to moult into the fourth stage. From the above data the length of time after hatching required to reach the fourth stage at 22.2°C. is the same as that shown in figure 1; at 18.3°C. it is one day longer; and at 15.6°C., 2 days longer than in figure 1. Thus the methods used by us in rearing larvae experimentally at St. Andrews gave approximately the same results at the higher temperatures as were obtained in experiments under possibly more natural conditions at Wickford. It is probable, therefore, that figure 1 gives a very good approximation of the length of the larval period at various temperatures in nature.

SALINITY

Gompel and Legendre (1927), working on the European lobster (*Homarus vulgaris*), concluded that the larvae die when the specific gravity of the sea water is below 1.017, and also that larvae can stand a density of 1.033. They make no mention, however, of feeding the larvae or of rearing them through successive moults at different salinities, although both first and second stage larvae were used in the experiment.

TABLE I. Survival at low salinities

Salinity range (‰)	Initial no. (stage 1)	Number reaching stage			Average no of days to stage 4
		2	3	4	
Experiment A (*Temperature range 15.1-17.2°C. Larvae kept in electric light during day and darkness at night*)					
31.8–30.9	12	11	11	10	26.9
28.4–27.6	12	11	8	8	25.0
25.5–24.7	12	9	7	4	26.5
22.5–21.8	12	11	8	7	26.9
19.8–19.0	12	9	5	1	29.0
Experiment B (*Temperature range 15.0-17.5°C. Larvae kept in electric light during day and darkness at night*)					
31.8–30.1	12	12	11	10	22.9
27.2–26.3	12	10	9	8	22.5
22.1–21.1	12	10	9	8	22.1
17.0–16.4	12	4	0		
11.8–11.4	12	0			
Experiment C (*Temperature range 17.5-20.2°C. Larvae kept in complete darkness except while changing water*)					
31.2–30.8	24	20	19	19	13.4
25.9–25.4	24	18	18	16	13.0
21.5–20.7	24	20	19	17	13.1

Table I shows the effect of different salinities on the survival and length of period between hatching and the fourth stage, temperature, food and light conditions being the same for all larvae in the same experiment. Experiment C, because of the greater number of larvae used, is of relatively greater importance than experiments A and B in regard to the effects of salinity between 31 and 21 per mille.

In all experiments the normal salinity at St. Andrews, about 31 per mille, proved most suitable for survival, while salinities of 28 per mille and lower were slightly more unfavourable. Salinities even as low as 21 per mille, however, were only slightly less favourable to survival than 31 per mille. (Even the small difference in favour of 31 per mille may have been due to the fact that the eggs for several months before hatching had been developing at St. Andrews in water of this salinity). At 19.4 per mille, however, the effect was definitely unfavourable, only 1 out of 12 larvae reaching the fourth stage (table I). In another experiment 2 out of 6 larvae were reared to the fourth stage at 18 per mille as compared with 4 out of 6 at 21.5 per mille. A salinity of 16.7 per mille was definitely harmful, only 4 out of 12 larvae reaching the second stage and none moulting into the third or fourth stages, while of 12 first stage larvae at 11.6 per mille 11 lived for less than 1 day, 1 lived for 1½ days, none moulting into the second stage (table I).

In each experiment the larvae at different salinities were kept at temperatures not differing at any time by more than 0.1 or 0.2°C. As shown in table I, there was very little if any significant difference in the length of time required by the larva after hatching to reach the fourth stage at salinities from 31 to 21 per mille: the time may even be slightly less at about 25 and at 21 per mille than at 31 per mille.

Higher salinities than the normal at St. Andrews were obtained by slow evaporation of sea water by exposing it in shallow basins to the sun's rays. At a salinity of 42.5 per mille 6 recently hatched first stage larvae died in from 4 to 8 days without moulting, 2 of the larvae dying while in the act of moulting, while at 34.9 to 35.3 per mille in the same experiment of 6 similar larvae hatched at the same time from the same lobster, 3 reached the third stage, 2 the fourth stage and 1 was alive in the fifth stage at the close of the experiment.

Growth on Moulting

Table II shows the size attained by fourth stage larvae at various salinities between 31.4 per mille and 19.4 per mille. While the growth per moult could not be determined, since it was found impossible to collect more than a few of the first stage shells, it is indicated by the size of the fourth stage lobsters that salinities as low as 19 to 21 per mille had no unfavourable effect on the growth per moult of lobster larvae.

Table II. Average sizes of fourth stage lobster larvae raised from hatching to the fourth stage at different salinities. Larvae measured by ocular micrometer.

	Experiment A					Experiment B			
Approximate salinity (‰)	31.4	28.0	25.1	22.2	19.4	31.0	26.8	21.6	
Number measured	10	8	4	7	1	10	8	8	
Carapace length to tip of rostrum (mm.)	5.85	5.78	5.65	5.94	6.10	5.94	5.91	5.98	
Carapace length to bottom of eye socket (mm.)	3.72	3.66	3.62	3.81	3.87	3.75	3.72	3.72	
	Experiment C			Experiment D					
Approximate salinity (‰)	31.0	25.7	21.1	31.0	30.0	29.1	28.2	27.3	26.4
Number measured	19	16	17	2	4	4	6	5	3
Carapace length to tip of rostrum (mm.)				5.75	5.74	5.68	5.87	6.03	6.15
Carapace length to bottom of eye socket (mm.)	3.90	3.85	3.96	3.58	3.66	3.67	3.75	3.80	3.85

LIGHT

Thirty-six first stage lobster larvae were placed in almost complete darkness immediately after hatching and the same number were kept in the ordinary light

of the laboratory at St. Andrews about one foot (30 cm.) away from a northwest window. The larvae were in sunlight for not more than half an hour a day at sunset. An attempt was made to keep the larvae in complete darkness, but a very small amount of light (much less than that of moonlight) may have had access to some of the jars. Again, the changing of the water was carried out in the ordinary light of the laboratory. Temperature and food were kept constant.

Ninety-four per cent of the larvae survived to the fourth stage in darkness and 78 per cent in the light (table III). In one experiment it took an average of 3 days and in the other 4 days longer to reach the fourth stage in the light than in the darkness. In both experiments also the fourth stage larvae reared in the dark were significantly larger than those reared in the light (table III).

Hadley (1906) placed 13 fourth stage lobsters immediately after moulting on June 23, in wire baskets, with bottoms 7 or 8 inches (ca. 19 cm.) below the surface in Wickford harbour. These fourth stage lobsters were in full sunlight and required an average of 14.5 days before moulting into the fifth stage, while 9 fourth stage lobsters also moulting into the fourth stage on June 23 and kept in the same place but protected from the light, being kept in light equivalent to twilight, spent on the average only 12.2 days in the fourth stage. Six of the lobsters kept in the sunlight grew on the average 14.4 per cent on moulting from the fourth to the fifth stage, while 7 of the lobsters kept in twilight grew on the average 18.2 per cent.

Huntsman (1924) in several experiments found that recently hatched lobster larvae usually died before reaching the second stage if kept exposed to the direct rays of the sun in still water in glass jars—an occasional larva reaching the second stage and not passing beyond this stage, while in jars shaded from the direct rays of the sun and dark jars similar larvae reached the fourth stage, the greatest number of survivals being in the dark jars. (All 3 sets of jars were kept under approximately the same conditions as regards temperature, food, salinity, etc.).

An experiment, however, carried on by the author in 1933 reveals the ability of lobster larvae to withstand a very large amount of light (at least after the light has passed through clear glass). Two first stage lobster larvae were placed, immediately after hatching, one in direct sunlight near the window of the laboratory, and the other with the sides shaded by tar paper from the direct rays of the sun but with top and bottom unprotected from diffuse light. The bottles were shifted so as to have the advantage of all sunlight after 10.00 a.m. Occasionally during the days with most sunlight the temperature was 0.1 or 0.2°C. higher in the light jar than in that with the sides protected from direct sunlight. The experiment lasted from July 23 to September 28, during which time each lobster moulted 5 times. The periods required for the 5 moults in the case of the 2 larvae showed no significant difference. In order to reach the larvae in this experiment the light had to pass through about 1 cm. of ordinary clear glass and from 0 to 9 cm. of sea water.

Conclusions

According to the above experiments it is evidently possible for an occasional lobster larva to survive fairly strong sunlight, at least if partially protected from

TABLE III. Survival and growth of lobster larvae in the ordinary light of the laboratory and in almost complete darkness

Condition of light	Number reaching			Days to reach the fourth stage		Carapace length* of fourth stage lobsters to bottom of eye socket	
	Stage 2	Stage 3	Stage 4	Average	Range	Average	Range
Experiment E (24 larvae in each lot. Temperature range 15.8-22.8°C.)							
Light	24	22	19	17.5	16–20	38.9	37–40
Darkness	24	24	23	14.5	12–17	41.2†	38.5–43
Experiment F (12 larvae in each lot. Temperature range 14.5-19.9°C.)							
Light	12	11	9	23.2	20–26	37.7	36–40
Darkness	12	12	11	19.0	17–22	40.8	39.5–43.5

*Length of carapace expressed as units on ocular micrometer scale, 31.4 units on scale = 3.0 mm.

†21 measured.

short wave ultra-violet light by glass in the first 3 stages, or as in the case of Hadley's fourth stage lobsters merely by a few inches of sea water. However, both our experiments on the free swimming first, second and third stages and those of Hadley on the fourth or lobsterling stage show that ordinary daylight which has passed through about 5 mm. of glass and direct sunlight shining on lobsters submerged a few inches in wire baskets have a detrimental effect on the larvae, lengthening the period required for moulting, lessening the amount of growth on moulting, and, in our experiments, lessening the chances of survival as compared with lobsters kept in almost complete darkness.

Many factors may be responsible for the unfavourable effect of strong light on the survival and growth of lobster larvae. Some of these are mentioned by Hadley (1906). Young lobsters from the fourth stage onward are not inclined to eat while disturbed by bright sunlight. The animal remains in the darkest part of the jar and usually refuses to eat. This does not apply with so much force to the free swimming young, but the large number of setae they possess renders them especially liable to weighting down by the large quantities of diatoms and stalked protozoa which develop rapidly in the light. In addition the light may produce a direct harmful effect which in the case of larvae kept in bright sunlight and only protected by a few inches of water may have a lethal effect.

FOOD

Three experiments were carried out on the relation of quantity of food to the survival and growth of lobster larvae. In all experiments some of the larvae were fed the usual amount of live copepods, some approximately one-half, some

one-quarter, and the remainder approximately one-eighth of the usual number. Live plankton food (mostly copepods) was added to the usual 250 cc. of sea water in each jar, using a wide mouthed pipette, the plankton sample being stirred continuously to obtain an equal distribution of the animals. The number of copepods added to jars containing one-eighth the usual amount of food ranged from 10 to 40 during the course of the experiments, the usual number being about 25. All the bottles in each experiment were kept in dim electric light at the same temperature, the temperatures in the individual bottles in experiments G and H not differing at any time by more than 0.1° and in experiment I by 0.2°.

TABLE IV. Average number of days required to complete the various larval stages under different food conditions, and number of larvae surviving through successive stages out of a total of three larvae for each food condition in experiment G, four in H, and three in I.

Amount of Ipankton fed	In first stage		In second stage		In third stage	
	No. of days	No. of larvae	No. of days	No. of larvae	No. of days	No. of larvae
Experiment G (Temperature range 12.8-14.6°C.)						
Usual	8	3	8	3	13	2
1/2	8	2	17*	2		
1/4	8	1				
1/8	8	1				
Experiment H (Temperature range 12.7-14.4°C.)						
Usual	7½	2	10	2	13	2
1/2	9½	4	14½	3	26	1
1/4	11	4	17½	2		
1/8	13	4				
Experiment I (Temperature range 15.1-18.0°C.)						
Usual	5½	2	7½	2	11½	2
1/2	5½	3	12⅔	3	37	1
1/4	7½	2				

*After the period indicated the larvae died without further moulting.

Table IV shows the average time required for the various larval moults to occur under the above conditions. Very few larvae survived more than one moult when the food supply was lowered below half of that normally given, and in those which survived a progressively longer period was required between moults as the food supply was decreased. Each stage on a reduced food supply apparently also took a progressively longer time. Thus first stage larvae fed the normal and half the normal amount of plankton respectively in two experiments required approximately the same time before moulting into the second stage, and in the third required only 25 per cent longer, while in the two experiments in which larvae fed half the usual amount lived beyond the second stage, they remained 45 and 69 per cent longer respectively in the second stage, and 100 per cent and 222 per cent respectively longer in the third stage than lobsters fed

the normal amount of plankton. It is a fact, however, that at each successive stage the larva, being larger, would require a greater food supply while the actual amount of plankton food added was approximately the same at all stages.

In the above experiments of 10 larvae used under each of the food conditions, 6 reached the fourth stage under normal feeding and 2 when fed one-half the usual amount: no larva fed one-quarter the usual amount lived beyond the third stage and none fed one-eighth the usual amount survived beyond the second stage.

PROBABLE EFFECTS OF TEMPERATURE VARIATION ON NATURAL SURVIVAL

Our knowledge is too incomplete to attempt at this time any general account of the application of the above results to survival of the lobster larvae in nature. However, a certain aspect of the effect of temperature will be dealt with as illustrating the nature of the problem.

Table V gives the range in temperature from May to November, 1931 and 1932, in Malpeque bay, Prince Edward Island, one of the warmest areas on the Maritime coast and where a large lobster population exists.

In such warm areas of the gulf of St. Lawrence as western Northumberland strait and Malpeque bay the author (Templeman 1936) has shown that hatching begins in late June and is practically over by the end of July, probably as much as 95 per cent of the hatching being over by this time and all hatching being completed before the middle of August.

In Malpeque bay in 1931 and 1932 surface temperatures at Hog Island reef ranged between 17 and 21°C., and bottom temperatures between 14 and 21°C. in 1931 and 14 and 20°C. in 1932 from about the first of July to the middle of September. At a temperature of about 18°C., which is approximately what the larva would encounter in this area during the above period, the fourth or lobsterling stage is reached in about 15½ days, and the fifth or the first definite bottom stage in about 32 days after hatching (figure 1). Consequently even the few larvae hatched in Malpeque bay during the first part of August will have reached the fifth stage by the middle of September. Furthermore, from the middle of September to the middle of October the bottom temperature ranged from 9.4 to 14.5°C. in 1931 and from 11.5 to 16.7°C. in 1932. In our experiments at 19.5°C. at St. Andrews recently moulted fifth stage larvae took 14 days to moult into the sixth stage. Calculating from this figure and from the length of time spent in the fourth stage in figure 1 at 19.5 and 13°C., we conclude that the fifth stage at 13°C. would last about 29 or 30 days before moulting into the sixth stage. Consequently the great bulk of the larvae in the Malpeque bay region, hatching in July, will have moulted beyond the sixth stage, and many even of the few hatching during the first half of August should reach the sixth stage before winter, thus ensuring a better chance of survival than if winter caught them in some earlier stage less fitted for bottom life.

Except in limited inshore areas in Malpeque bay, the surface water does not usually rise above 21°C. and the bottom temperatures above 20°C. In our ex-

TABLE V. Range of surface and bottom temperatures taken weekly at Hog Island reef, Malpeque bay, in 1931 and 1932, depth 30 to 48 feet (9 to 15 metres). (Data provided by Dr. A. W. H. Needler, Prince Edward Island Biological Station.)

Month	Temperatures 1931 (°C.)		Temperatures 1932 (°C.)	
	Surface	Bottom	Surface	Bottom
May	5.2–13.6	4.0–11.5	11.2–11.4	6.0–10.0
June	11.4–14.5	9.6–12.1	11.8–16.2	10.2–17.8
July	17.2–21.1	13.8–20.2	17.3–19.5	16.8–19.2
August	20.2–21.1	18.9–21.4	19.4–21.1	19.2–19.7
September	11.7–17.4	11.6–16.4	14.8–20.1	14.5–19.2
October	9.9–12.6	7.2–12.2	10.8–15.1	10.4–14.5
November	5.3– 8.7	4.6– 8.7	5.3– 7.3	5.0– 7.5

periments larvae were reared to the fourth stage at 24°C. and by Huntsman (1923) at 25°C. Consequently since Malpeque bay represents one of the warmest areas containing large quantities of lobsters, it is unlikely that temperatures too high for the survival of larvae can be encountered anywhere on the coast of the Maritime provinces.

Possibly the lowest summer temperatures of inshore water in the Maritime provinces occur at the mouth of the bay of Fundy. Data on the time of hatching at Grand Manan are available from observations in running water tanks at St. Andrews in 1933. Eight egg-bearing lobsters obtained directly from the Grand Manan fishing grounds were placed in the tank on June 10. The first female began hatching during the last week of July. On August 6 from one female the larvae were almost completely hatched, on another the larvae had begun hatching and 6 had not yet begun hatching. By August 14, 5 females had completely hatched, 2 were hatching and one had not yet begun hatching. The last record of larvae being collected from the last Grand Manan female to hatch her eggs was on August 23. Temperatures in the tanks from June 12 to August 15 ranged from 10.4 to 14.1°C. These temperatures are several degrees higher than the Grand Manan lobsters would have encountered near Grand Manan and consequently these lobsters would have hatched still later if they had been allowed to remain on the fishing grounds at Grand Manan, and hatching in the tanks probably occurred at least a week earlier than would have occurred in nature at Grand Manan. Thus whereas in the warmer parts of the gulf of St. Lawrence the greatest amount of hatching occurs in July, at Grand Manan hatching is about a month later, with its probable maximum during the second and third weeks of August, most of the hatching being probably over by the end of August.

Table VI shows the average daily surface temperature of the sea from July

to November, 1931 to 1933, at a point near Seal cove, Grand Manan. Owing to the great tides in this region the early morning surface temperatures would be essentially the same as the inshore bottom temperatures in this area. Inshore temperatures averaging between 10 and 11°C. occur in August, September and October. At 10.5°C. larvae require 48 days to reach the fourth stage and 87 days to reach the fifth stage (figure 1). Consequently a larva hatching at Grand Manan on August 15 could in the inshore waters reach the fourth stage by October 2, and have completed three-quarters of the fourth stage by October 30. At the average temperature of 7.6°C. found in November the remaining one-quarter of the fourth stage would be completed in 20 days (calculated from figure 1). Thus the larva would moult into the fifth stage about November 20, and with steadily decreasing temperatures no further moulting would occur during the winter. A larva hatching on August 25 would by the same calculations reach the fourth stage by October 12 and have completed half the fourth stage

TABLE VI. Surface temperatures for a point near Seal cove, Grand Manan, taken daily at 8.00 a.m.

Month	Temperature range (°C.)			Average daily temperature (°C.)			
	1931	1932	1933	1931	1932	1933	Average 3 yrs.
July	8.7–11.8	7.6–10.3	7.9–10.9	9.7	8.4	9.6	9.2
August	9.4–12.9	9.8–13.4	9.3–11.3	11.0	10.8	10.3	10.7
September	10.0–12.3	10.3–12.5	10.0–11.0	11.1	11.4	10.5	11.0
October	7.0–10.9	8.4–11.7	7.0–10.7	9.8	10.6	9.6	10.0
November	5.4– 9.9	2.8– 9.5	2.2– 9.4	8.7	7.6	6.6	7.6

by October 30. Since by calculation from figure 1 the fifth stage at 7.6°C. would last 80 days, the remaining half of the fourth stage would not be over by the end of November, and since by this time the temperature of the inshore water at Grand Manan is usually in the vicinity at 3 to 6°C. it is unlikely that any further moulting occurs.

Thus in the Grand Manan area if temperature were the only unfavourable factor most of the lobster larvae in the inshore waters could theoretically reach the fourth stage before moulting ceases for the year. Some of them may reach the definitely bottom stage—the fifth stage, while others are unlikely to reach the fifth stage before low temperature after the end of November puts an end to moulting. Under these conditions the larvae are much less fitted to survive the first winter than are the sixth to eighth stage lobsters of the warmer areas, which are larger and more definitely adapted for bottom living than the fourth and fifth stages.

It is hardly to be doubted also that the free swimming larval period before the fourth stage is the most defenceless period and the time of greatest mortality, consequently when this larval period is lengthened from about 15 days in Malpeque bay to about 48 days at Grand Manan, the chances of survival to the bottom living stage are greatly lessened.

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The Food of Salmon Fry in Eastern Canada

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ABSTRACT

Stomach analyses were made of young salmon in their first summer, as obtained from West and East Apple rivers, and Reeds and Eatonville creeks, all in Cumberland county, Nova Scotia, and from Digdeguash river in New Brunswick.

Chironomid larvae formed the chief food of the newly emerged fry, while ephemerid nymphs constituted the major food taken during the mid-summer growing period. Trichoptera tended to become important toward autumn, but at times formed a considerable proportion of the food even in July and August. Plecoptera, simuliids and tipulids also occurred, and terrestrial forms such as Hymenoptera, Homoptera and Diptera were taken in appreciable quantities in late summer and autumn.

It is now recognized by those engaged in fishery researches that a knowledge of the natural food of various species of fishes is a prerequisite of a rational program for the distribution of fry. Numerous investigations have been made concerning the food of many species of fishes, but it would appear that although the Atlantic salmon has been artificially propagated in many countries and is one of the fishes which has been most studied, its natural food during the fry and parr stages has been largely neglected.

Regarding the food of salmon fry, Hutton (1924, p. 16) states as follows: "Shortly before the contents of the yolk-sac are entirely absorbed, the alevin or rather the fry, commence to feed on tiny insects." In his recent monograph on the salmon Kendall (1935, p. 68) has said,—"The food of the fry is largely Entomostraca and small insects, and larger crustaceans and insects as it increases in size."

During our investigations on the salmon at Apple river and elsewhere, we have collected from time to time random samples of fry and parr for stomach analyses. In collecting these specimens special precautions have been taken so that the operations or the presence of the collector would not make available to the fish to be taken food organisms which otherwise they would not get. To insure this we have avoided wading in the stream above the specimens before seining, and seinings have been made mostly with small seines against the current; but in the few cases where conditions did not permit this, the hauls were made very rapidly down the stream, with the net and the collector moving faster than the current. If such precautions are not taken when collecting stream fishes which are to be used for food studies, the analyses may not give a true conception

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of the foods usually available to the fish. In the summers of 1932, 1933 and 1934 young salmon were collected from the two branches of Apple river and two other nearby streams in Cumberland county, Nova Scotia, and during 1934 from the Digdeguash river in New Brunswick. Up to the present, food analyses have been completed for the young salmon only during their first summer. For these food studies 324 specimens of fry-of-the-year were collected. All specimens were preserved in formaldehyde solution immediately after capture and the food analyses made later when facilities were available. The stomach of each specimen was opened and the food examined under a dissecting binocular microscope. In making the identifications of food organisms, few attempts have been made to carry the identifications beyond the family and in many cases only to the order. The number of each group of organisms in each stomach was determined and its percentage volume estimated. Owing to the small size of the organisms and their variety, no method of making very accurate volumetric calculations appeared practicable. In determining the relative volumes of the various classes in each stomach content, some small organism or piece of food was selected as a unit for comparative estimation of the volumes of the others and the percentage volumes calculated from the numbers of each present. When the separate stomachs of one lot of fry had been thus treated, the averages of the various percentage volumes of the different classes of organisms were then determined.

In studying the food of a fish which occupies such a wide range of stream habitats as does the young of the Atlantic salmon, a considerable amount of work would be required for a detailed study of its food even in a single stream. Besides the differences in the habitat, seasonal changes within each habitat and even daily or hourly fluctuations in the available foods might have to be taken into consideration. These analyses deal with the dominant classes of foods taken by the young salmon from the time of their emergence from the gravel in June until October, when their feeding is beginning to decline. The differences in the relative quantities of the various classes of organisms taken on different dates in any habitat may be due to availability of the organisms, or to the fact that those fish collected at a later date are larger than those taken earlier. A few other factors indicating irregular changes in the foods taken will be dealt with later in the discussion of the food.

WEST APPLE RIVER

The specimens of this collection were taken from a quarter of a mile (0.4 km.) of West Apple river having alternate pools and gravel rapids with little variation throughout the area. On June 14 the first specimens were caught soon after they had emerged from the gravel and collections were continued periodically until October 15. During this time the fry had grown from an average length of 25.5 mm. to an average of 70.5 mm.

The first lot (WA. 1) of 7 fry, averaging 25.5 mm. in length, was taken on June 14, 1932, from a shallow gravel rapids. All of these fry had completely absorbed their yolk sacs, but had yolk-fat stored in their fat reservoirs. Six of them had their stomachs nearly full, but the one most immature had taken only three small organisms. This specimen contained 1 minute chironomid pupa, 1

small chironomid larva and 1 hydrachnid. The others had fed largely upon small larvae and small pupae of species of chironomids. One individual had eaten 5 small ephemerid nymphs, another had taken 2 simuliid larvae, while 3 of them had each secured a plecopteran nymph. The organisms taken were 44 chironomids, 5 ephemerids, 2 simuliids, 3 Plecoptera and 1 hydrachnid. Their stomachs contained an average of 7.8 organisms each.

A second lot (WA. 2) of 26 fry, averaging 28.8 mm. in length, most of which had been out of the gravel for several days, was taken on June 23 from a rapids similar to that from which the first lot was taken. These fry had consumed 2,123 chironomid larvae and pupae, but mostly larvae, 48 ephemerid nymphs, 3 trichopteran larvae, 1 simuliid larva, 1 plecopteran nymph and 1 collembolan. They contained an average of 83.3 organisms each.

These two lots of fry indicate the nature of the first food taken by the fry. Immature chironomids form the major food with ephemerids, simuliids, Plecoptera and Trichoptera forming smaller percentages (table I).

TABLE I. Food of salmon fry from West Apple river, N.S., 1932

Chiro. —Chironomidae
Ephem. —Ephemerida
Trichop.—Trichoptera
Simul. —Simuliidae
Plecop.—Plecoptera
Terr. —Terrestrial forms

Lot no.	Date	Average percentage volume						
		Chiro.	Ephem.	Trichop.	Simul.	Plecop.	Terr.	Misc. aquatic organisms
	1932							
WA 1	June 14	67.0	11.2	....	3.3	18.5	....	
WA 2	June 23	92.3	6.2	1.0	0.04	0.4	0.04	
WA 3	July 5	47.1	41.1	3.7	....	6.6	....	
WA 4	July 15	41.4	57.9	0.3	0.2	....	....	Diptera 0.12
WA 5	July 27	23.2	73.4	0.4	0.6	....	....	Coleoptera 2.3
WA 6	Aug. 15	41.7	50.1	2.3	3.5	....	....	Coleoptera 2.3
WA 7	Sept. 16	36.7	22.8	25.2	1.8	0.2	13.2	Hydracarina 0.11
WA 8	Oct. 4	0.4	20.9	62.1	....	2.2	11.7	Odonata 2.5 Tipulidae 0.2
WA 9	Oct. 15	0.6	30.6	54.4	....	5.0	8.7	Coleoptera 0.6

Three lots of fry (WA. 3, WA. 4, and WA. 5), totalling 47 individuals, were taken from the same general area as the above on July 5, 15 and 27 respectively. In the food of these three lots chironomids change from being the main food to a secondary position and ephemerids become the dominant food, reaching their highest percentage of 73.41 per cent on July 27. Simuliids, Plecoptera and Trichoptera formed small percentages of their food.

A collection of fry (lot WA. 6) taken on August 15 shows a decline in the importance of the ephemerids which have fallen to 50.1%, with chironomids rising to 41.7%. By September 16 (lot WA. 7) the food shows a still further decline in the percentage of ephemerids, with chironomids once more becoming the primary food. However, by this time, Trichoptera have become second in

importance with ephemerids slightly lower. By the latter date land forms have first made their appearance as a food of some significance, forming 13.2%. Simuliids and Plecoptera occur only in small quantities.

Two lots (WA. 8, WA. 9) totalling 23 fry, collected on October 4 and 15, show that Trichoptera have become the major food with ephemerids second. Land forms are still of considerable importance with chironomids forming only 0.4 and 0.6% on the respective dates. It should be noted, however, that the October specimens had not fed well and many of the stomachs were only partly filled.

These collections of fry during their first feeding season from West Apple river in 1932 form our most complete series from a single habitat. The average percentage volumes of the various classes of organisms are given in table I, while

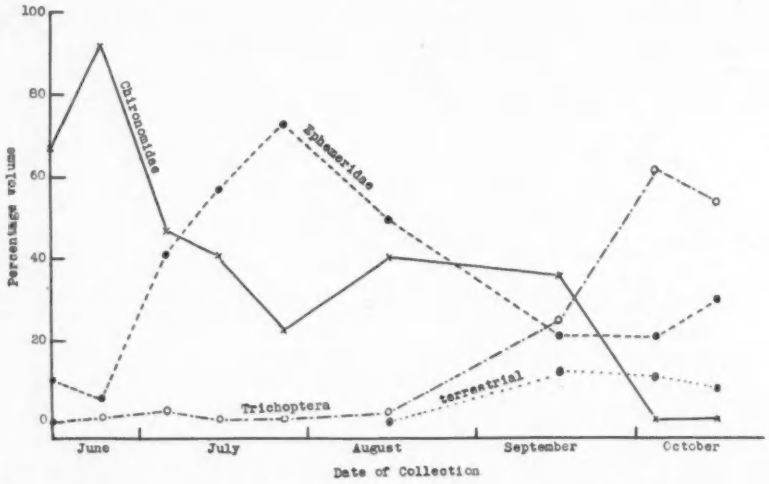

FIGURE 1. Average percentage volumes of Chironomidae, Ephemeridae, Trichoptera and terrestrial forms found in collections of fry taken from West Apple river, during the summer and fall of 1932.

in figure 1 graphs showing the percentages of chironomids, ephemerids, Trichoptera and terrestrial insects are shown. In 1933 a small series of four lots was taken from West Apple river and the analyses of these show somewhat similar conditions.

EAST APPLE RIVER

During 1932 six lots of salmon fry (EA. 1 to EA. 6) which had been previously planted, were taken from the lower part of East Apple river, and during 1933 three lots of native fry were collected from the same area. These collections totalled 60 fry and the results of their food analyses are given in table II. Composite graphs of the food of the fry taken in the two years are shown in figure 2. A comparison of these graphs with those for the same classes of organisms from

the West Apple river collections of 1932 (figure 1) will reveal striking similarities. Here also the decline in the percentage of chironomids is shown during late July and early August concurrently with a rise in the ephemerids. Trichoptera percentages rise in September, but do not exceed those for ephemerids as in the West branch. The land forms become relatively important during the fall months just as they do in the West branch.

REEDS CREEK

On July 30, 1932, a lot of 6 fry averaging 42 mm. in length, was taken from Reeds creek, a small stream some 10 miles (16 km.) south of Apple river. In the region where these fry were taken the stream has a fine gravel and sand bottom.

TABLE II. Food of salmon fry from East Apple river, N.S. (abbreviations as in table I)

Lot No.	Date	Average percentage volume				
		Chiro.	Ephem.	Trichop.	Terr.	Misc. aquatic forms
	1932					
EA 1	Aug. 3	5.0	87.2	7.7	....	
EA 2	Aug. 15	27.3	55.8	8.7	....	Plecoptera 7.8 Diptera 0.3
EA 3	Sept. 1	8.8	33.0	11.5	39.8	Simuliidae 2.8 Tipulidae 1.17 Coleoptera 1.17 Lepidoptera 1.12
EA 4	Sept. 16	23.4	48.6	14.9	8.9	Plecoptera 3.6 Simuliidae 0.6
EA 5	Oct. 3	6.8	59.5	32.8	0.8	
EA 6	Oct. 15	6.0	41.2	30.8	18.7	Plecoptera 3.3
	1933					
EA 7	June 30	47.6	49.5	....	....	
EA 8	Aug. 15	46.4	53.6	....	....	
EA 9	Sept. 1	47.0	41.0	6.4	1.4	Plecoptera 2.0 Coleoptera 0.6 Chaetopoda 1.6

These fry contained an average of 82.5 chironomids each with an average percentage volume of 57.5, which is higher than the percentages for chironomids at that time in Apple river. They contained an average of 5.3 ephemerid nymphs each with an average volume of 41.3%. All other organisms made up a percentage volume of only 1.2. These analyses agree well with those of Apple river in that chironomids and ephemerids constitute at this time almost the entire food.

A collection of five fry averaging 63.6 mm. in length from this same stream on September 20, shows chironomids still as the major food, forming 44%, but ephemerids are down to 14% and Trichoptera up to 18.4%. For the first and only time in these food analyses tipulid larvae were found as one of the major food organisms. These 5 fry contained an average of 3.8 tipulid larvae each,

with an average percentage volume of 23. These larvae were mostly species of *Antocha*. All other organisms in this lot constituted 0.6%.

EATONVILLE CREEK

On September 3, 1932, a collection of 14 fry, averaging 56.5 mm. was seined from Eatonville creek, a small rocky stream near Apple river. These fry contained average percentage volumes as follows: chironomids 19.3, ephemerids 68.9, Trichoptera 10.4, all other forms 1.4. This lot shows a lower percentage of chironomids than the specimens in either branch of Apple river at this time, but a much higher percentage of ephemerids. Trichoptera average about the same as in Apple river but land forms are entirely lacking.

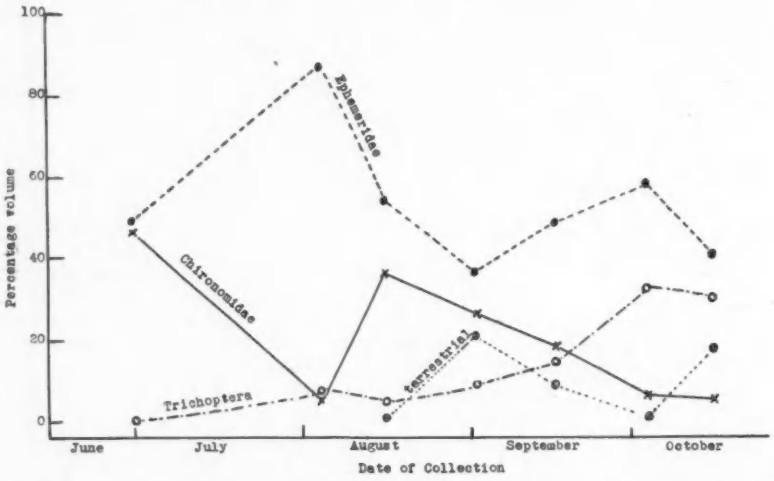

FIGURE 2. Average percentage volumes of Chironomidae, Ephemeridae, Trichoptera and terrestrial forms found in the collections of fry from East Apple river, during the summer and fall of 1932 and 1933 combined.

DIGDEGUASH RIVER

The Digdeguash river flows into Passamaquoddy bay a few miles from St. Andrews, N.B. This stream presents a great variety of stream habitats and supports a large population of young salmon. Collections were made during 1934 from this stream as follows: July 17, 20 fry; August 1, 13 fry; August 17, 14 fry; September 1, 12 fry (September 1, branch stream, 4 fry). The results of the analyses of the stomach contents of these specimens are given in table III. The fry from the main stream were taken from shallow slow-flowing rapids having gravel and sand bottom.

The food analyses of these show a consistently high percentage of ephemerid nymphs and a low percentage of chironomids. Unlike Apple river, Trichoptera

reach their highest percentages during July and August, instead of September and October. Simuliids and Plecoptera occur in insignificant quantities and tipulids are lacking. A considerable assortment of miscellaneous foods, however, forms an appreciable percentage of the stomach contents (table III). The terrestrial forms included Hymenoptera, aphids, Diptera and Coleoptera.

A collection taken in a rocky branch of this river on September 1 shows a high percentage of chironomids and Trichoptera, but a lower percentage of ephemerids than the collection from the main stream. The food of the fry in the branch is more comparable with that of Apple river specimens at a similar time.

Food found in the stomachs of one lot (D. 4) taken at 10 p.m. from the main stream is almost identical with that found in their stomachs during the daytime, but, since their rate of digestion of such organisms is unknown, these results may not be significant.

TABLE III. Food of salmon fry from Digdeguash river, N.B., 1934 (abbreviations as in table I)

Lot no.	Date	Average percentage volume						
		Chiro.	Ephem.	Trichop.	Simul.	Plecop.	Terr.	Misc. aquatic forms
	1934							
D 1	July 17	8.9	79.7	9.7	0.1	0.4	1.1	
D 2	Aug. 1	9.5	74.6	13.0	....	2.8	....	
D 3	Aug. 17	7.1	75.4	1.1	....	....	6.7	Odonata 4.7 Gastropoda 5.0
D 4	Aug. 17 night	8.0	75.7	0.5	0.7	....	8.7	Coleoptera 6.2
D 5	Sept. 1	11.1	62.3	....	....	1.4	22.3	Gastropoda 2.8
D 6	Sept. 1*	15.0	45.0	40.0	....	....	....	

*Branch stream.

Terrestrial forms included Hymenoptera, aphids, Diptera, Coleoptera.

CONCLUSIONS

These food analyses, although only preliminary in a study of the food of the salmon fry, show the importance of certain classes of organisms. Chironomids in their immature stages constitute the most important food for the newly emerged fry. Ephemerid nymphs are extremely important as a food and may be regarded as the major food taken during the mid-summer growing period. Trichoptera in most instances have attained importance toward the end of the growing season. However, in the Digdeguash river (main stream) they were taken in appreciable quantities during July and August. Another exception occurred on July 17, 1933, in a collection from West Apple river when Trichoptera were found to constitute 31.8% of the food. This was due to an emergence of a single small species on this date and the fry were feeding upon the emerging imagines. Plecoptera were found in small quantities in the early summer and again in the fall collections. Simuliids were taken by the fry in limited quanti-

ties. Tipulid larvae were taken occasionally in most of the habitats but one lot from Reeds creek showed a relatively high percentage. Terrestrial forms occurred in appreciable quantities in the food during the later summer and fall. The highest value found was 39.8% in the East branch on September 1, 1932, during a flight of formicids. Other Hymenoptera, Homoptera and Diptera also occur among the terrestrial forms taken.

Whether or not the fry do any selective feeding can only be determined by further research, but no doubt the smaller fry select the smaller organisms. This may account for the predominance of chironomid larvae and minute pupae in the smallest fry. It should be borne in mind that many species of chironomids are nearly microscopic in the mature stages and that the newly hatched young of such species are extremely small. It seems probable that the general character of their food is determined largely by availability, which may vary from day to day as certain swarm phases in the life histories of the various species occur. It would appear that young chironomid larvae may become available in large numbers during dissemination a short time after hatching.

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